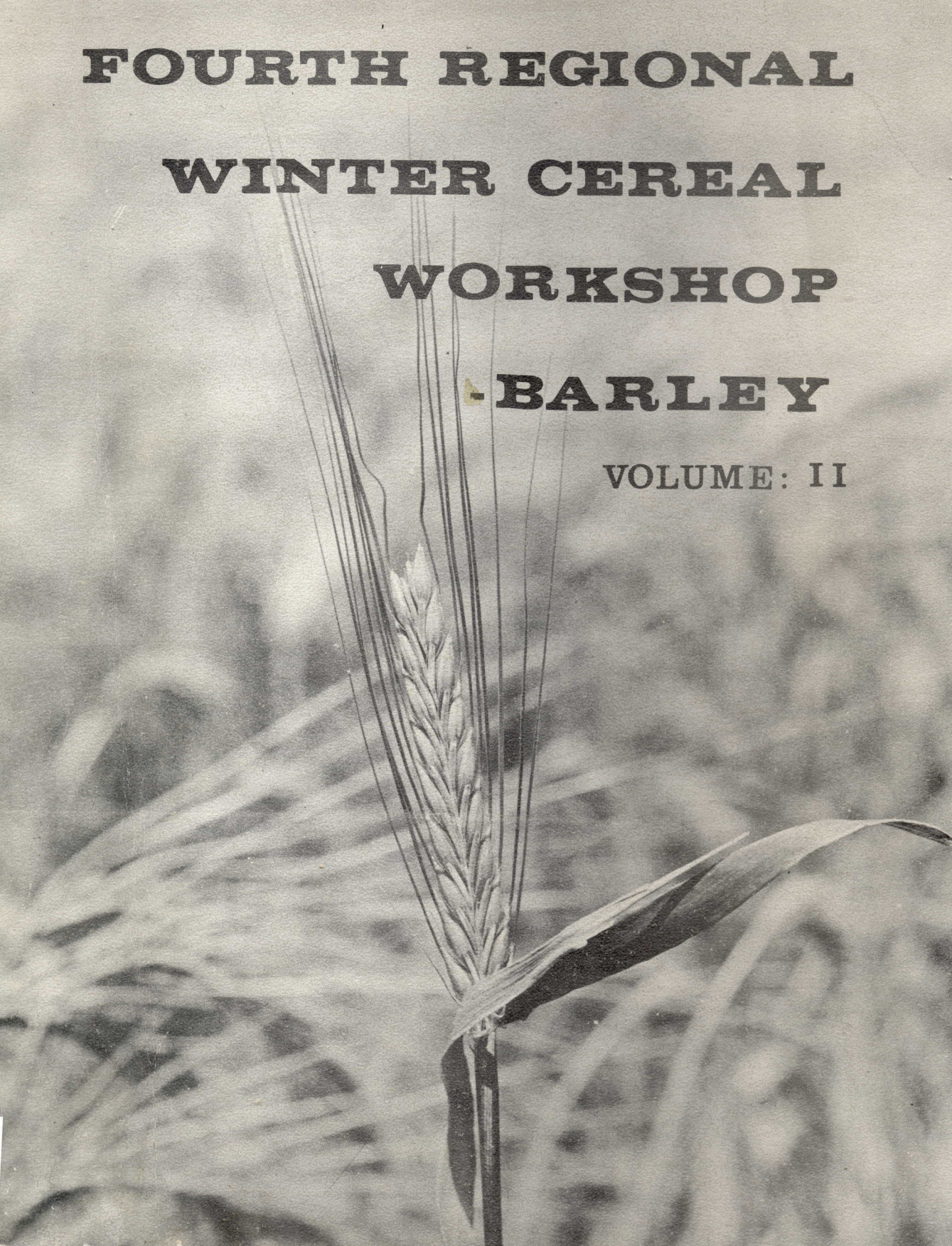
FOURTH REGIONAL WINTER CEREAL WORKSHOP

-BARLEY

VOLUME: II



FOURTH REGIONAL WINTER CEREAL WORKSHOP -BARLEY

VOLUME: II

AMMAN - JORDAN

APRIL. 24-28, 1977

BARLEY : Volume 2

Proceedings:

Fourth Regional Winter Cereals Workshop

Amman, Jordan

24 - 28 April, Jordan

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BARLEY WORKSHOP

FOREWORD

Human use of barley goes back to the dawn of history. This staple grain has been an essential part of the staff of life for man and beast for thousands of years, and has contributed more than is often appreciated to the development of civilization as we know it today.

Barley traditionally was the energy food of the masses. Significantly, it was barley loaves that provided the basis for the miraculous feeding of the multitude in New Testament times. Of equal significance is the fact that in modern times an index of social progress is the extent to which barley is disappearing from human diet to be replaced by wheat.

The trend is currently active and change is so rapid that the status of barley in the Mediterranean area at the present time is largely unassessed as far as human life-styles and national agricultural programs are concerned. There is need for an up-to-date appraisal of the role and importance of barley in the countries of North Africa and Western Asia.

This need is fully appreciated by the staff of the International Center for Agricultural Research in the Dry Areas (ICARDA), which was established in January 1977 to improve food production in the Mediterranean lands and associated countries. ICARDA was set up under the aegis of the Consultative Group for International Agricultural Research, and prominent in the mandate given to it by CGIAR is responsibility to carry out research on improvement in barley. For such research to be effective, benchmarks are needed to enable progress to be measured and signposts are required to mark the way for future activities.

The Barley Workshop described below was held in Amman, Jordan, in April 1977, to establish the benchmarks and signposts to which reference has just been made. About 120 scientists from more than 40 countries met for five days at the University of Jordan to discuss the present status of barley production and use; to assess the problems affecting its cultivation; and to advise on the strategy and methods for future research. The results of these discussions form the report to which this is a foreword.

It should be emphasised that the Workshop has established the continuing value of barley in many countries of the world. This report constitutes a major contribution for such a vitally important crop, which remains supreme in its ability to tolerate drought conditions and to accept levels of salinity and soil infertility that rule out the cultivation of wheat.

While it is true that its direct use as human food has declined over the centuries, it is also true that barley's use for animal production in various forms makes it of ever-increasing importance in societies where the consumption of animal protein is rising year by year. Added to this is the little publicized growth of the brewing industry in the developing countries which sets new standards of quality and quantity of demand.

The future of barley is assured and this report provides a much-needed and suitably authoritative basis for research by ICARDA and other similar institutions and national programs in the years to come.

Harry S. Darling
Director-General - ICARDA

INTRODUCTION

The publication of the Proceedings of the Fourth Winter Cereal Workshop held in Amman, Jordan, from 24-28th April, 1977, is a continuation of a series which had its origins in Beirut, Lebanon, in 1972. The First Workshop was concerned with three main subject areas: diseases, reviewing the status of Septoria, tritici and yellow rust (Puccinia striiformis) in the region; agronomy, and the status of agronomic research in the area; and, a review of the known sources of resistance to Septoria and yellow rust. The Second Regional Wheat Workshop in Ankara, Turkey, in May 1974, was concerned with tillage and cultural practices for wheat under low rainfall conditions. The Third Regional Wheat Workshop was held in Tunis, Tunisia, in 1975, and focused on the subject of durum wheat improvement, weed control, crop rotation with annual forage and legumes, and seeds.

The philosophy behind the Workshops has been to provide a forum for the exchange of information for active cereal research workers in this area of the world. The Workshops have usually been scheduled every two years and the topics covered have been those currently in need of attention. The Workshops have been a stimulus to the presentation of the most recent research results which could be used by fellow colleagues.

The Fourth Workshop in this series designated Barley as an appropriate and opportune subject. The current Workshop has drawn from a much broader base than previously because of the smaller number of workers in this region, and the additional support and interest provided from sources other than the traditional ones of FAO of the United Nations, the Rockefeller Foundation, the Ford Foundation and CIMMYT. Additional support and funding for this Workshop has been provided by the Montana State University-United States, Agency for International Development (AID) and the International Center for Agricultural Research in the Dry Areas (ICARDA). The barley research group at Montana State University initiated the idea of a conference on barley in the Middle East. The original suggestion was for the conference to be held in Lebanon in 1976, but the civil war during this period forced a postponement of these plans.

With the Regional Workshop scheduled for 1977 the merging of the two programs into a collaborative effort seemed to make a great deal of sense. The topic of barley, with all of its production potentials and problems, was a relevant one and a subject needing attention. The convening of the Barley Workshop in the Middle East also provided barley research workers from all areas of the world with an opportunity to become familiar with the newest International Agricultural Research Center, ICARDA.

One of the major responsibilities of ICARDA is the production and improvement of small grain cereals in the Middle East Region. The mandate includes a primary responsibility for the development of barley germplasm. Together with CIMMYT (International Maize and Wheat Improvement Center - Mexico) the establishment of ICARDA should strengthen the research and production needs in this region and other areas of the world.

The development of the program for the Barley Workshop was drafted by staff members from CIMMYT, ICARDA and Montana State University. The Ministry of Agriculture, Government of Jordan, and the Faculty of Agriculture, University of Jordan, graciously extended an invitation to act as the hosts for the Workshop. It should be mentioned that the efforts of our hosts were invaluable and without their active efforts this Workshop would not have been possible. All of us extend a special appreciation to the local organizing Committee for arranging such a delightful and beneficial stay in Jordan.

We were honored to have His Royal Highness, the Crown Prince, present the Welcome Address and officially open the conference. We regret that we are not able to record and include his stimulating address in the proceedings.

As in any large gathering, a number of changes are required depending upon the circumstances prevailing at the time. Thus the schedule of the program is not identical to the one originally presented by the organizing committee.

During the process of arranging the papers and reports it became obvious that the amount of information presented was substantial and of two distinct types. For this reason it was decided that two volumes would better serve the interests and needs of barley researchers. In the first volume we have collected together the country reports and abstracts that refer to the production and usage of barley and which illustrate its current importance. While in the second, we have attempted to group together those papers which review the current state of knowledge on barley research and production methods and work. Needless to say, some papers fall somewhere in between these guidelines. The Editors assume the responsibility for modifying some papers and any inadequacies thereby introduced. Hopefully our efforts have been accurate and beneficial. For any errors or oversights we humbly apologize. The publication of these two volumes is a joint undertaking by ICARDA and CIMMYT. A special word of appreciation needs to be extended to Mrs. Nada Khattar who typed, re-typed and helped in so many ways to get the proceedings published. Without her we would still be editing.

The Editors
Aleppo, Syria
January, 1978.

THE PROSPECT FOR FUTURE WORLD FOOD SUPPLIES

By

R. G. Anderson*

Your Royal Highness, Excellencies, Mr. Minister, President of the University, Dean of Agriculture, Colleagues.

It is a real pleasure for me to have been asked to speak on the future of world food supplies to this barley conference here in Amman. It is always a pleasure to be back among the many friends in the Middle East with whom I have worked during the past years. This workshop is one of a series which started several years ago. They have gained a great deal of stature over the years and are now looked on as one of the more potent voices of scientists in this very large region comprising of the Middle East, North and East Africa. I am sure that these deliberations on barley will form a bench mark from which future research will be dated.

The subject of the future of world food supplies is very broad indeed and to cover it in any depth would require several hours of our joint deliberations. For this reason, I have chosen to speak primarily on three fundemental areas, giving particular emphasis to the cereals which are so important in human nutrition and among which barley stands fourth in area and production, and third in yield.

The three fundemental considerations we must face if we are to provide food for the immediate future are:

1. We must make every endeavour to encourage and promote family planning to limit population growth.

2. We must attempt to have the present technology of food production fully applied on the widest possible front.

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3. We must establish a system of storage to allow the produce of the good years to cover the shortfalls of the poor while at the same time giving the farmers a fair profit return and thereby promoting a steady, forward thrust in production.

Let us know consider these salient points which are so critical to our survival as a species.

1. Population

Over his long history man's numbers have grown at an ever-increasing rate. At the outset he was a hunter and a gatherer. This was a chancy affair and by the time agriculture came into being (about 8000 B.C.) his total numbers are estimated to have been only about 10-15 million people, scattered across the globe. By the birth of Christ it was estimated that the number of people had increased to 250 million, by 1650 A.D. to 500 million, by 1850 to 1 billion, by 1930 to 2 billion and by 1975 to 4 billion. One may observe the decreasing period for doubling (i.e. the increasing rate of population increase).

We may ask then, "Can we control the population monster.?" Malthus[1] warned us, "Can we hope to feed a population double the number now living".

The answer of course is simple. We must control the increase of our numbers or famine, privation, and political chaos, will ensue. We must further develop the capacity to feed double the present world population as there is little chance that we will be able to reduce the rate of population increase before this figure is reached. There will thus probably be a need to use repressive measures, at least in some cases, to limit population growth.

In looking at the control of population growth, there appear to be some bright spots but in other areas even the beginnings of control are yet to come.

Legalized abortion, admittedly the least desirable method of control, is now available in one form or another to the people of two thirds of the countries of this world; Lester Brown[2] states that a high percentage increase in population occurred in

1970. In the five years since then, however, the percentage has declined from an overall 1.9 percent to 1.64 percent. Western Europe and North America, excepting the Latin countries of North America, are at present near the zero increase level. In five years China's increase dropped from 3.2 to 1.9 percent and East Asia's as a whole from 1.85 to 1.18 percent.

However, all areas are not bright spots, and there are a number of negative signs. Eastern European, African and Latin American countries as a whole are either maintaining previous high rates of population growth or, in some cases, registering an increase. Mexico, for example, with a rate of 3.6 to 3.8 percent, adds more people to the world per year than the combination of United States and Canada.

Judged at a 1.8 percent increase (accepted by some as the world rate) our present four billion people will become eight billion sometime during the year 2013. What this means in food terms is that in the next 3.6 decades, we must produce double the amount of food we were able to amass, through continued increments, in the last 997 decades (the time elapsed since agriculture began). This is a sobering thought to anyone who thinks of the magnitude of the task.

Can this challenge be met ? If so, how ?

2. The Physical Resources to Produce Food and their Application

According to FAO[3], only about 11 percent of the land surface of the earth can be classed as arable. Other sources consider this figure could be doubled but it would be at the expense of forests and pasture areas. However, it is obvious that such lands could not be expected to be equally as productive as the presently cultivated areas. Further, such areas are normally more easily eroded, and hence destroyed. Most of the new land that could be brought into cultivation lies in South America and Africa.

Water Supply and Use

Very often land is under- or non-productive, because of a lack of fresh water. Only about four percent (approximately 1000

cubic kilometers) of the runoff water is at present used for irrigation and this on only ten percent of the cropped land. Further, rainfall is very unevenly distributed; for example, South America has 33 percent of the runoff but only 15 percent of the land, whereas the Middle East, North Africa, Mexico, Southwest United States Temperate, South America and Australia receive 5 percent of the runoff and have 25 percent of the land. The potential for irrigation primarily exists in South America and parts of Africa. One of the great problems, however, is that even the present systems of irrigation are often poorly organized. It is estimated that to repair the present systems, install the new irrigation systems required and modernize the agriculture of Asia, Africa and South America, would require the expenditure of about 700 billion US Dollars in today's value, or if spent at 30 billion per year it would take 25 years to accomplish. This is a great deal of money but if estimated alongside the world's present defence expenditure of 280 billion per year, a better perspective is achieved.

Unfortunately, the inauguration of new dams or new irrigation systems has great political appeal, whereas repairing old systems or installing drainage systems has little. Yet, when drainage is not installed and erosion is not controlled, salinization and silting rapidly reduce the advantages gained in installing new water supplies.

Water use can also be improved through greater economy. Drip irrigation in certain desert countries, use of trained irrigators in Taiwan, charging for water use, and better cultural practices to preserve soil water and control weeds are examples of ways in which water can be more economically used. Turkey, by improving its cultural practices in recent years, has been able to show a 70 percent increase in productivity. A further benefit of such improvements is that with better water management and an assured supply, farmers are encouraged to increase their investment in agriculture.

Fertilizer Use

Another factor to consider in increasing the food supply is the increased use of fertilizers. A well nourished plant, like a human being, is much more productive. There is much talk of the value of organic fertilizers, but although recycling of these resources should be carried out wherever possible, the fertilizer need is vastly greater

than the supply from these sources. The amount of organic manures needed to replace the 47 million tons of fertilizer N used in 1975 would make a road 118 meters wide x 2 meters deep around the equator and would require at least twice the number of animals now living to produce. Therefore, in view of the impossibility of relying solely on organical fertilisation, we are faced with the need to use increasing amounts of artificially produced fertilizers.

Ewell[4] considers that seven billion dollars per year should be invested in fertilizer plants up to 1980. The Chinese, who are the world's foremost users of composts, have contracted the building of thirteen 1000 ton per day, urea plants in addition to the many smaller ones now in use, to supplement their supply. It is considered that the world use of nitrogen fertilizer will increase by one quarter by 1980 and will certainly more than double by the year 2000. It is said that the production of N is very expensive in the use of fossil fuels or hydroelectric energy. Yet in one year the amount of gas flared in Saudi Arabia is more than that required to supply all the N requirements at present levels of use. N is also supplied by nitrogen fixation which produces about 150 million tons per year. However, this source may well diminish in the future as more food is required, and less legumes are likely to be grown.

Phosphorus is a non-renewable element, but reserves which should provide P for several centuries at the projected level of use of the year 2000 are already known.

Potash, is less used than the two major elements and although this is also a non-renewable resource, very large supplies are available in Canada and other nations, so that for many centuries to come, supplies of this element are unlikely to become limiting.

One of the areas which receives less attention is that of micro-nutrients. There are many areas of the world where specific micro-nutrients already limit crop production and such areas will increase in size and frequency of occurrence. The added strains on soil reserves of these elements, arising from greater crop off-take where multiple cropping is practiced or an increased use is made of major elements, will make the supply of micro-nutrients a much more limiting factor in crop production. Careful monitoring of the supplies of minor elements is now mandatory if yield levels are to be maintained or increased.

Sources of Food

The world population depends on cereal grains for 50 percent of all its protein and calorie consumption. If grain fed to animals is included up to 75 percent is supplied from the cereal grains. The food base is indeed narrow. For our primary needs we now rely upon about 11 species of food plants of which eight are cereals of the grass family. Land area devoted to cereals has risen by about ten percent in the past ten years while production has risen by 38 percent and yields by 25 percent. Thus, a net gain was registered in this period and we managed to stay ahead of population increase. The increase in yield and production has come from improvements in both genetic and agronomic technology. Thus far, however, only about 60-80 million hectares have been sown to new varieties of wheat (about 11-14 percent of the total wheat area) and about 60 million hectares to rice (about 17 percent of the present area). Thus there is much still to be achieved through wider use of high yielding varieties and a much greater exploitation of their yield potentials. India, for example, where more than 50 percent of the wheat is irrigated, averages only 1.3 - 1.4 tons/ha and the potential for the varieties grown is at least double this figure.

It is often said that when land food fails we can turn to the sea. This seems unduly over-optimistic since the sea presently supplies a little over two percent of man's food and we are told by those knowledgeable of the sea that the supply of sea food is decreasing because of over-fishing. Therefore it seems we must produce our extra food from the land. There is no alternative.

The Need for Chemicals

Chemicals used to control such pests as weeds, diseases and insects should be looked upon as the farmer's drugs for curing or preventing disease. Just as the doctor uses drugs to cure our ills the farmer uses chemicals to cure or protect his plants. Yet there is a wide movement among environmentalists who live in cities to prevent farmers using chemicals, proclaiming they are poisoning the planet. Truly, care must be taken, but is slow starvation a suitable alternative to the use of chemicals, which can ensure food production ? The critics, however, are people who have never been hungry and who believe that food grows in supermarkets. We must wake up and condemn this irresponsible action or we will have this starvation at our doorstep.

3. Grain Supply and Storage - Policy Developments

Cereals, because of their dominant position in our food supply and their perishable character, need to be treated in a different way from other foods if we are to maintain production. Under the present system, farmers are encouraged to produce in times of shortage. They respond and with great supplies the price falls and they are left "holding the bag".

It is very peculiar that we have not been able to successfully duplicate Joseph's experience(5) in storing through the good years for use in the lean years. Yet, this is the only way in which sustained growth in production can be achieved so that increasing populations can be fed.

From the end of World War II up to 1972, the grain exporting countries, the United States, Canada and Australia, had surplus supplies and were expected to act as food brokers for those countries perenially short in food supply. Surpluses are embarrassing, and grain was used as gifts or in concessional sales to needy countries. There were three results of this policy - famine was averted; surpluses were distributed so that the efficient farmers in the exporting countries were allowed to produce while tax payers were relieved of the burden of taxation to pay for the storage; and the importing countries were lulled into a false sense of security that cheap food would always be available and easily imported so that it was not necessary to worry about developing their own agriculture. Furthermore, this cheap food was used to keep prices in the cities low and prices to home producers were correspondingly low resulting in little incentive to produce food at home. To make matters worse, the money realized from the sale of the grain was used for industrialization and not for developing agriculture.

A few countries such as India and Pakistan, saw the error of this approach, albeit somewhat late, and decided to do something about it.

This led to the large change in production which has been termed the "Green Revolution".

In 1972 when the stocks of surpluses in the world disappeared and prices rose, many of the countries began to realize that they were extremely vulnerable to similar developments in the future. The disappearance of these stocks as Hathaway(6) points out, set off the

wage/price spiral from which we are only now recovering. As the percentage of income spent on food increased, fixed incomes would not stretch and industrial workers struck for higher salaries which of course further increased the cost of living. Thus the see-saw continued. The farmer was blamed for the higher prices but it was really in the food chain from producer to consumer that most of the price increases came about. For example, a loaf of bread with two and one half cents of wheat in it rose to five cents worth of wheat, but the price of that loaf rose from 25 to 50 cents in North America, and although the cost of wheat has since gone down the price of a loaf has continued to rise. This is indicative of the problems that arise as a result of shortages.

Adequate reserves are thus required in order to buffer wide fluctuations in price and to avoid boom-bust cycles in the farm economy, as well as to prevent inflation in the economy of the whole country.

The question immediately arises as to who will bear the costs of this storage and insurance against want. It is quite evident that the exporting countries are no longer willing to pay all of the costs. A number of countries, for example, the USSR, Japan, Israel and Poland, have entered into agreements with the United States to take a certain quantity of grain each year. This tends to level out the supply and demand curves but additional similar agreements are now necessary worldwide. At present international work is being undertaken to try to increase the productivity of the developing nations, and some countries are now attempting to establish substantial domestic reserves. All of these moves will help to establish insurance against want in individual countries but to make this a reality in the world situation there is a need to establish international granary reserves located at strategic points in the world into which different countries can sell their surpluses. This must be financed by the international community as a whole. In this way we can use the produce of the good years to satisfy the needs of the poor.

Forecasts for future food needs, as one might expect, indicate a shortfall of up to 100 million tons by 1985/86 even with a healthy increase in productivity, but with a lesser rate of gain in productivity the shortfall could reach 200 million in this period. The worst shortages naturally would be expected in countries, least able to afford the import of food. Thus about 50 percent of the deficit would be expected in Asia,

20 percent in North Africa and the Middle East, 15 percent in the Sub-Sahara countries of Africa and 15 percent in Latin America.

Time does not allow the enumeration of the ways in which these shortfalls can be avoided but suffice it to say that the nations of the world are learning more about the methods by which a solution can be devised. The world is gradually awakening to the need for more attention to the food front and it is hoped that for a period anyway we can continue to feed the world's increasing numbers. However, this is only a palliative and the real solution lies in limiting our numbers if we are to not only have food but also some of the other things which make life worth its being lived.

I should like to close with a quotation by David Hopper[7], President of the International Development Research Centre of Canada. 'It is important to recognize that the world's food problem does not arise from any physical limitation on potential output or any danger of unduly stressing the "environment". The limitations on abundance are to be found in the social and political structures of nations and the economic relations among them. The unexploited food resource is there between Cancer and Capricorn. The successful husbandry of that resource depends on the will and actions of man'.

This statement succinctly expresses the present state of the art. Food can be grown if there is a will and an economic approach which provides incentive to the farmer to grow larger crops. If we reduce our population and apply the already known technology to fully exploit the production potential we will have sufficient food, less pollution and a better standard of life on our planet in the future.

Literature Cited

1. Malthus, T.R.,
An Essay on the Principles of Population, London, 1978.
Reprinted for the Royal Economic Society, London 1926.
Pages 11 and 13 to 16.

2. Brown, Lester.
World Population, Signs of Hope, Signs of Stress.
Worldwatch Paper No.8, October 1976.

3. Anonymous. FAO Production Yearbook 1975.

4. Ewell, R.
World Plan of Action, Fertilizer Industry.
Unpublished Paper - UNIDO/Vienna, March 1975.

5. The Bible - Genesis.

6. Hathaway, D.E.,
Grain Stocks and Economic Stability.
Unpublished 1976.

7. Hopper, W.D.
The Development of Agriculture in Developing
Countries. Sci., American. September 1976.

BREEDING AND VARIETAL IMPROVEMENT

THE MOST IMPORTANT PROBLEMS IN THE EUROPEAN MEDITERRANEAN AREA

By
Comenge, Ensenat Jesus*

The climatic conditions in the Mediterranean area determine the kinds of agriculture being practiced. Dry and poor soil areas are dedicated to the cultivation of cereals.

Fallowing is often practiced and in years of cropping low yields (less than 1,500 hg/ha) are common. Those areas where rainfall is more abundant allow continual cultivation without fallowing and irrigated areas only exist on flat-land with prolonged drought in summer.

The cultivation of barley in dry areas generally comes at the end of the cereal rotation. In the areas with less rainfall, winter barley is cultivated to take advantage of the seasonal rains, while spring barley is used in areas where there is a higher percentage of annual rainfall. Therefore, taking France as an example, with 2.779,000 ha in 1975, only 550,000 ha were dedicated to winter varieties. The land dedicated to winter sowing is being increased due to the appearance on the market of two-row varieties of (a) long cycle and (b) elevated yields.

The dry and continental areas, which comprise large areas of cultivated barley, commonly have cold periods in the spring. These areas require long-cycle varieties to avoid frost and those capable of rapid maturity to avoid shrivelling.

There is also the ever present risk of strong winds with harmful effects mainly in the period of maturity. This provokes the problems of shattering, head breakage, shrivelling and lodging which are of special importance in the years of higher rainfall.

The incidence of fungus diseases is variable from one year to next depending on climatic conditions. They are especially serious in the years with mild and rainy winter and spring conditions and are enhanced by the existence of barley in the last step of cereal rotation.

Barley used for brewing, normally of two rows, presents a particular problem depending on the standards required of the breweries. Examples are: the speed of germination (energy for germination), dormancy, grain homogenity, colour, fineness of grain cover, low protein content and the quality of starch etc.

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* Agronomist, Paseo Maria Agustin 4,
Zaragoza, Spain

Requirements of malting barleys must follow a different line of improvement in comparison with those for other purposes, where the high protein content is the base in increasing quality.

The Mediterranean countries with low or no rainfall in spring and summer, where the cultivation of spring cereals (maize and sorghum) is possible without supplemental irrigation, makes annual production of winter cereals questionable.

Concerning barley for feeding (approximately 80% of the total), the problem consists not only in raising the content and quality of protein, but also in lowering the content of raw fiber and petosanas in order to modify the quantity of maize in the formulae for feeding the monogastric animals.

Objectives for the breeding of Barley

Realizing all the problems previously described, the principal lines of improving barley in which research is being made are:

1. Breeding local populations:

   1.1. - Breeding for better adapted local populations to the environmental conditions.

   1.2. - Crossing with conveniently selected parents for increasing the potential productivity of local varieties, taking advantage of their coarseness.

   1.3. - Backcrossing profitable local varieties as recurrent parents, to introduce desirable genes and to conserve the primary desirable characteristics.

2. Progressive breeding and obtaining new varieties:

   2.1. - Improvement of the productivity.

      2.1.1. - Dwarf and lodging resistance.

      2.1.2. - Resistance to diseases.

         2.1.2.1. - Resistance to *Helminthosporium sp.*

         2.1.2.2. - Resistance to *Erysiphe gr.*

         2.1.2.3. - Resistance to *Puccinia sp.*

         2.1.2.4. - Resistance to *Ustilago sp.*

         2.1.2.5. - Resistance to *Rynchosporium*

         2.1.2.6. - Resistance to Barley Yellow Dwarf virus.

2.1.3. - Resistance to accidents.

2.1.3.1. - Resistance to Shattering

2.1.3.2. - Resistance to Cold

2.1.3.3. - Resistance to Shrivelling

2.2. - Breeding for quality.

2.2.1. - Introduction of high protein and lysine content.

2.2.2. - Breeding of quality by reduning raw fiber (nude barley)

2.2.3. - Breeding quality barley for brewery.

2.2.3.1. - Yield by extracting

2.2.3.2. - Breeding for grain characteristics.

3. Hybrid Barley

3.1. - Utilization of cytogenetic techniques such as, balanced Trisomic.

These are in general, the principal objectives of breeding in the Mediterranean area. Without doubt, the particular problems which are presented in the Mediterranean area will need other breeding objectives. Nevertheless, those that we have presented reflect, in our opinion, the problems faced in the breeding of barley.

BIBLIOGRAPHY

1 - ALLUE ANDRADE, J.L.

1966 - Subregiones fitoclimáticas de España. Ministerio de Agricultura Madrid.

2 - BERGAL, P.

1968/69 - Característiques Qualitatives des Orges de Brasserie. Melhoramento - vol. 21

3 - BIEL, A. y GARCIA DE PEDRAZA, L.

1962 - El clima de Zaragoza y ensayo climatológico para el Valle del - Ebro. Ministerio del Aire - Publicaciones.

4 - FAO

1972 - Production Yearbook. Vol. 26 - Roma

5 - FAO

1975 - Production Yearbook. vol. 29 - Roma

6 - INIA

1970 - Programa Nacional de Investigación Agraria. Departamento de Cereales y Leguminosas de grano. Ministerio de Agricultura - Madrid.

7 - INRA

1954, 1955 y 1957 - Rapport D'activite Centro de Reserches Agronomiques de Versailles.

.../...

8 - INRA

1963 - Rapport D'activite
Centro de Recherches Agronomiques du Midi
Ecole Nationale Superiure Agronomique Montpellier.

9 - MATALLANA VENTURA J.

1962 - Cebadas para Malteria - INIA, Bol. 46

10 - MINISTERIO AGRICULTURA

1975 - Anuario de estadística Agraria 1974 - Madrid.

11 - DECE

1951 - Developpement des Pâturages et de la Production Fourragere dans les pays Mediterraneens. Paris.

PERSONAL COMUNICATIONS TO THE AUTHOR

1 - BAYCHELIER, G. - Union des Cooperatives Agricoles de Semences de Provence. Arles (France)

2 - BEZOT, P. - Bureau de Gestion des Variétés. INRA - Versailles - (France)

3 - CHERY, J. - Station D'amelioratón des plantes. Ecole Nationale Superieure Agronomique. Montpellier (France)

4 - LEFEBURE, J. - Florimond Desprez. Templeuve (France)

5 - SIMIAND, J.P. - Semences D'elite Secobra. Maule (France)

BARLEY IMPROVEMENT AROUND THE WORLD

Robert F. Eslick*

An examination of the program of this workshop would indicate that we will hear much about the status of barley breeding around the world from people well qualified to discuss it from the various countries represented. A workshop such as this is not held to look backwards but to look to the future. Since this workshop is about international barley breeding it would be appropriate to look to the future of international barley breeding. As on-site breeders we should attempt to enumerate a number of objectives that we might reasonably expect an international program to accomplish. Let us assume a breeding program for all barley breeders and discuss some possible objectives applicable to all.

Objective I: To provide "resource breeding material".

Historically this has been in progress for years. It has had several facets, the most important of these have been: (1) the exchange of genetic stocks for such characteristics as disease resistance, height, lodging resistance, winter hardiness, malting quality, high lysine, etc; (2) the exchange of improved cultivars as they have been developed around the world; and (3) the general availability of germ plasm from the world's collections of barley.

Perhaps we should be concerned with the utility of some of the material received. So often the lines are essentially worthless for immediate use and can retard a breeding program several years. Use of some of these stocks can essentially mean starting a breeding program over for all desirable characteristics. We might also wonder about whether the stocks received include those that show maximum expression of the trait, e.g. seed size; all known resistance to a particular disease, e.g. net blotch, etc.

In terms of utility perhaps we should describe in more restricted terms the nature of the "resource materials" we would like to receive as on-site breeders. These materials should:

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1. Require a minimum of screening by the on-site breeder.

2. Reduce or eliminate the general need for expensive laboratory equipment and/or associated highly trained personnel.

3. Provide a source of unusual gene combinations.

4. Provide a source of plants with maximum expression of selected traits.

5. Provide a means of inexpensive, large scale recombination, at the breeder's option, for progressive improvement.

Given the characteristics of the "resource materials" that might be useful in most any breeding program there are certain stipulations and/or restrictions that should be placed on the manner in which these materials are developed. Five are discussed.

1. Utilize to the maximum possible the genetic diversity present in the world barley germplasm banks. We have continued to add to these germplasm banks and provide for expensive maintenance. There is no evidence we have given sufficient consideration to methods that would best utilize this germplasm. Complete cataloguing of useful traits could be advantageous but expensive and never complete. Available "elite" sets of stocks from the USDA collection is a useful step in this direction but may represent only a small portion of the genetic variation for a given trait, e.g. disease resistance. We have found a bulk of all accessions to be useful for certain purposes. With 18,000 accessions in the USDA collection alone it will probably require two hectares or more of spaced plants to minimize genetic drift in a bulk of that collection. Individual identities are lost but these may not always be important.

2. Take advantage of the "happy home" concept which sets forth the proposition that many genes are in genetic backgrounds that do not permit their full expression or utilization. Whether we define these as epistatic effects, minor genes, pleiotropic effects, linkage, etc., is of little consequence. The principle can be demonstrated quite easily with isogenic lines. Extensive recombination is required to place specific genes, represented in world collections, in gene combinations where their true potential can be expressed.

3. Minimize genetic vulnerability to stress. This could well include reduced vulnerability to such items as disease, drouth, lodging, alkaline or saline soils, cold temperatures, soil fertility, etc. Two approaches are possible, pyramiding major genes or accumulating minor genes. Multi-lines of either or both of the above may provide additional protection.

4. Take advantage of the principles of the "vector-analysis" approach to plant breeding. Basically this provides that the population mean for all desired traits of the resource material used for selection or exploitation be as near as possible the mean of the ideal variety for a given environment. This may be accomplished by careful selection of original parents, top crossing, backcrossing, or selection within a segregating population before exploitation.

5. Must consider all major desirable traits for the program to be the most effective. This would have to be a long term goal if all diseases, quality factors, maturities, agronomic traits etc. are considered.

Objective II. To provide the most convenient way possible of "exploiting" the "resource material" provided. Four items are enumerated.

1. Provide techniques for screening of very large population, preferably on an individual plant basis, for as many traits as possible.

2. Provide information on pleiotropic effects of traits so that they may be used to advantage or selected against as the situation requires.

3. Provide a convenient method of establishing "instant" homozygosity of plants or "instant" homogeneity within lines in any early generation, preferably without resorting to haploidy or other expensive inefficient techniques.

4. Do not provide "resource material" that regularly requires purification or elimination of selected lines segregating for unacceptable genes, e.g. recessive genetic male sterility.

If we were to agree to the general desirability of Objective I and accompanying requirements the general techniques are available. However, we probably lack information on the best method of procedure, if there is any one best method.

Under Objective II, items one and two are reasonably straightforward and merely require much hard work and experimentation to provide useful techniques and information. Items three and four require additional stocks or genetic information to accomplish.

Role of Genetics

Barley has the fewest chromosomes of any of the commonly grown cereal grain crops and thus is probably the most subject to genetic manipulation. More is known about the genetics and cytogenetics of barley and more "genetic" stocks are available than for any crop with the possible exception of corn.

It is unfortunate that relatively few geneticists have attempted to use genetics to improve the plight of the barley breeder. If a plant breeder attempts to do this he may become rather frustrated with the lack of genetic information and stocks. Needed information and stocks become quite apparent if the geneticist will consider the plant breeder's needs. I would like to refer to three instances where genetics have been used to advantage to efficiently isolate desired stofks or genes for useful purposes in plant breeding.

A few years ago we wished to couple two male sterile genes approximately one recombination unit apart. We started with a conventional genetic approach and found the task impossible at our level of operation. By utilizing coupled marker genes and proper crossing procedures the task was easily accomplished.

The second example involved using mutagens to obtain haploviables at a specific site (near the msg 2 locus) in the chromosome compliment. This work was done by Dr. Juan Hernandez, a graduate student of Dr. R.T. Ramage. In a haplo-viable, only one type of pollen grain accomplishes fertilization, in this instance the one carrying the msg 2 allele. At the time this work was initiated, possible success was questioned by many since such genes had not been described in barley. By chemical mutagensis in populations established with proper marker genes for ready recognition of haploviability Dr. Hernandez isolated and identified 24 haplo-viables at or near the msg 2 locus. Since then we have found them rather generally distributed over the entire chromosome compliment.

The third example also involves chemical mutagenesis in properly marked populations. The problem was to develop a series of translocations with lethals in or very near the interstitial segments. We have accomplished this for 20 reciprocal translocations in the world collection. Given adequate genetic information about a gene, these stocks can be used to develop plants or populations that are readily visually recognizable homozygotes for specific genes. Plants homozygous for lysine genes, disease resistant genes, etc., may be established without resorting to lysine determinations or exposure to the pathogens, etc. These stocks can be very useful in establishing "resource breeding materials" with specific genes homozygous with minimum involvement of time and money.

The three discussed applications of genetics and cytogenetics were to review some of the accomplishments when mutagens are applied to the proper genetic materials. Perhaps a look to the future at what the plant breeder might reasonably expect from the geneticist will not then seem quite so unrealistic. Most immediately we need methods to eliminate male steriles from a population, once introduced and secondly to provide for "instant" homozygosity or homogeniety within selected lines.

If we were utilizing dominant male sterile genes, rather than recessive male sterile genes, any selected fertile plant would not segregate for male sterility. Genetic stocks and methods are available for finding this type of male sterile mutant and, to some, would increase the utility of populations.

Proceeding to the second useful trait, we do have such a mechanism available in Dr.K.J.Kasha's method of producing haploids, which involves emasculation, pollination, and chromosome doubling, which lacks utility on a large scale basis and assumes certain minimum facilities and expertise not generally available. Perhaps a gene that results in haploidy could be found. Over the years we have collected spontaneous semi-steriles. Upon closer examination some of these collections have been shown to have well developed embryos but very poorly developed endosperms in what were first thought to be the "sterile" florets, i.e. xenia expressing recessive shrunken endosperm mutants. Some of these could represent haploid-producing genes. If so, such a gene would simplify and provide greater utility to the doubled haploid approach to "instant" homozygosity.

An even more satisfactory approach would be to locate a gene that would result in one type or another of apomixis. Genetic stocks to construct systems for ready detection of apomixis among hundreds of thousands of plants are available. Modes of asexual reproduction are quite common in the family Gramineae. There is no reason to suggest that it cannot be found or induced in barley. The usefulness of such genes should be apparent to any barley breeder.

Conclusions

Some of the ingredients of a truly international barley breeding program have been enumerated. Obviously, not all breeders would have the resources or wish to participate in a major way, but all should have an opportunity to participate, contribute, and evaluate. The greatest short term benefits would be better sources of "exotic" germplasm to incorporate into on-site breeding programs, better criteria for selection with greater understanding, reduced genetic vulnerability, and, hopefully, reduced total effort to produce superior cultivars. Adoption of such a program does not mean that everyone abandons pedigree breeding tomorrow.

Methods of implementation of a truly international program of barley breeding could well be a topic for considerable discussion, but first it must be defined and objectives set forth. Perhaps the clues to implementation are present and partially activated within the framework of the International Barley Genetics Symposium.

Perhaps, the presentations, field trips, discussions, formal and informal, could result in some firm recommendations on International barley breeding.

BARLEY IMPROVEMENT IN AUSTRALIA AND ITS POTENTIAL CONTRIBUTION TO THE MEDITERRANEAN REGION

By

D.H.B.Sparrow*

The Australian Cereal Belt

Most of Australia's winter cereals are grown across a broad belt of southern Australia between 30°S and 40°S. This area, in the main, has a classic Mediterranean-type climate with a hot dry summer and predominantly winter rainfall. The crop growing season can vary from five to nine months depending on the distribution of the rainfall which can average from 250mm to 750 mm per annum. The marked seasonality of rainfall decreases from west to east whilst the incident increases towards the coast. Thus the cereal areas of Western Australia experience little or no summer rains which can, however, occur in Victoria and southern New South Wales, whilst the coast of Victoria and much of eastern Australia is too wet for winter cereals. (Figure 1).

Cereals are also grown in northern New South Wales and southern Queensland between 22°S and 30°S where summer rainfall predominates and winter crops depend on stored soil moisture, although in some winters occasional good falls do occur. This area shows some climatic similarity to northern India and Pakistan. Small areas of cereals are also grown in Tasmania, 42°S, where the mild, long season, maritime climate is similar to the more temperate parts of the northern Mediterranean countries.

Because of the generally arid climate of Australia relatively small quantities of water are available for irrigation, and only about 4 percent of Australian arable crops are irrigated. Irrigation of wheat and barley is quite rare; the available water is preferred for crops of greater economic return such as cotton, rice, citrus, vines and pastures for milk production. Modt Australian winter cereal crops are therefore grown under dryland conditions and are dependent on seasonal rainfall.

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The soils of the south eastern part of the Australian Cereal areas developed on limestone or from highly calcareous parent material are generally neutral to alkaline in reaction. Wheat is the favoured crop on the heavier soils while barley predominates on the lighter, particularly on the light sandy loams of the so-called Mallee soils which stretch in a wide belt across south eastern Australia. In Western Australia much of the cereal belt is situated on relatively acidic siliceous sands. In the more northerly cereal areas, particularly in Queensland, the soils are heavy, black and self-mulching with a higher natural fertility than in the south where either Trifolium subterraneum or annual Medicago spp in the pasture phase, on the more acidic and more alkaline soils respectively, are essential for the improvement and maintenance of soil fertility. In southern Australia very little fertilizer nitrogen is applied to cereal crops (not more than 30 kg/ha) whereas the use of superphosphate (averaging 100 kg/ha) is long established, and the addition of various trace elements is essential for good crop growth in some areas.

Seasonal Variability

It is characteristic of Mediterranean-type climates that rainfall is erratic and may be inadequate for crop growth at any time during the growing season. High evapo-transpiration from late spring onward can be a major factor in limiting crop yields. The length of the growing season, the distribution of rainfall particularly in spring, as well as spring temperatures, are all important factors in crop performance. Soil type, moisture retention and availability are associated contributing factors. In addition, crop growth may be restricted by low winter temperatures and in some areas frost damage at anthesis can cause a reduction in yield through damage to the developing grain. At harvest grain loss through shattering due to hot sirocco winds is also a possibility. The Australian cereal belt is exposed to all of these climatic hazards and a variability from year to year that can range from seasons of severe moisture deficit to those of above average rainfall causing loss of soil nitrogen by excessive leaching or crop damage by lodging. Thus cereal crops in Australia, particularly southern Australia, are grown under ecologically similar conditions to the cereal crops of the Mediterranean region.

It has long been recognized that edaphic variation between localities together with seasonal variation at any locality are large under Mediterranean dryland agriculture. This poses problems in the stability of crop production and it also poses a problem, particularly with regard to appropriate selection procedures, to the plant

breeder seeking to increase yields. In Australia over the past 30 years an additional, complicating, factor has been an appreciable increase in soil fertility in many cereal areas following the use of subterranean clover and annual Medicago species in pastures in the rotation. Economic factors have also influenced the relative proportions of the cereal areas devoted to wheat or barley and thus the environmental conditions under which these crops are grown. In general though barley is grown on the lighter more alkaline soils in the drier shorter season parts of the Australian cereal belt.

Both Frankel (1958) and Finlay and Wilkinson (1963) have discussed the strategies that can be used by the plant breeder to meet the need for varieties adapted to changing and changeable conditions. The choice lies between breeding either for a series of closely defined ecological conditions or for general adaptability to a considerable range of environments. The first approach, breeding for specific adaptability, may be satisfactory where the influence of factors limiting optimum crop growth are reduced by the addition of water and nutrients, but has serious limitations for dryland crops subject to erratic seasonal changes and where, as in Australia, extensive rather than intensive agriculture is practised.

In analysing the site and year effects on wheat yields in New South Wales, Pederson and Seif (1975) suggested that a single environmental factor dominated the variation between sites, between years and between site-year combinations. Earlier Cornish (1949, 1950) had suggested that the between year factor in the variation in South Australian wheat yields was rainfall, or rather moisture available to the plant, and it can be inferred that the same factor is operative between sites and between site-year combinations. There is certainly evidence (Sparrow 1972) that other factors influence site differences; these are probably edaphic and act on moisture availability, but they are of lesser importance than rainfall.

Genotype-environment interaction

Australian plant breeders have long been aware that genotypic differences in adaptability exist and of the importance of selecting for wide adaptability to optimise productivity in a variable environment. It was this preoccupation with the interaction between genotype and environment that led Finlay and Wilkinson (1963) to develop the linear regression technique of measuring adaptation and thus of being able to select for wide adaptability. More recent developments in such analysis (Eberhart and Russell 1966, Perkins and Jinks 1968), in

criticism of limitations to such analyses (Knight 1970), as well as the multivariate approach to the analysis, also an Australian development (Mungomery et al. 1974) have led to a greater understanding of genotype-environment interaction. Useful reviews of various statistical methods are available, by Freeman (1973) and Byth (1977) and a comparison of methods by Eisemann et al. (1977).

Following the CIMMYT procedure (Borlaug 1968), of growing two generations of material for selection per year, a winter one at Obregon at 27°N and a summer one at Toluca 18°N and 2,500m. altitude other breeding organizations have followed suit with, for example, generations in Canada and Mexico or Britain and New Zealand. There has been less scope for this procedure in Australia although small summer generations grown locally under irrigation have been used at the Waite Institute. Where latitudinal and/or daylength changes occur at the alternate sites selection for daylength insensitivity and wide latitudinal adaptability has resulted; this is apparent in the world wide success of the Mexican wheats. The Australian search for wide seasonal adaptability has been carried out by replicating selection at several sites in any one year and in applying an adaptation analysis to the results from several sites and several years. The success of this method is reflected in the local success of Australian barleys released over the last decade, and the relatively good performance of Australian bred material in trials and commercially across the Mediterranean Region.

The general philosophy of Australian barley breeders is therefore to accept the challenge of the erratic dryland environment and to select for varieties which perform relatively well across a range of environments and seasonal conditions. This means accepting the results of the dry years and poor sites as of equal importance for selection as the results from the good, high yielding environments. For example, in South Australia grain yield can vary widely between sites and between seasons at any one site (Table 1).

Barley has a special place as a dryland cereal because genotypes adapted to a wide range of environments can be selected. I would suggest that selection for response to water and fertilizer nitrogen is inappropriate for barley unless major areas of irrigated crop are possible in a particular area. It is usually more economic to use irrigation water on other crops including wheat. Australian experience has shown that barley is well adapted to the Medicago -

cereal rotation system, which, with barley, leads to a steady increase in soil fertility, in grain yield and in grain protein content. On the other hand under dryland conditions barley's response to applied nitrogen is unreliable and yield may even be depressed (Sparrow and Doolette 1975). The combination of ley farming and new varieties has considerably increased the production of the Australian barley crop, there is no reason to suppose the same cannot be achieved across the Mediterranean Region.

Development of the Australian barley crop

Table 2 illustrates the relative areas of wheat and barley grown in Australia over the past 30 years and Table 3 the State by State distribution of the crop in recent years. Wheat, after wool, has been the second most important Australian export crop for nearly 100 years. Consequently, barley and barley improvement has been overshadowed by the attention given to wheat improvement. Barley breeding programmes separate from wheat programmes and with full time barley breeders have only been in operation for the last 20 years.

A full account of the history of the barley crop in Australia is covered in Sparrow and Doolette (1975). Up until the beginning of this century British and some German two-row malting varieties were grown in Australia because they were preferred by the European trained brewers. The climate of southern Australia did not favour such varieties which, with a late flowering habit, need a long growing season. Their performance was erratic, the grain often shrivelled and of poor quality. The fortuitous discovery by Samuel Prior, a farmer in South Australia, of an early maturing line or spontaneous mutant in a crop of Chevalier early in the 1900's marked the beginning of the expansion of the Australian barley crop. Prior's Chevalier, or Prior, as it became known, ripened earlier than existing varieties and was thus better able to withstand the moisture stresses of late spring to produce good yields of well-filled grains acceptable to the local malting and brewing industry. It has since been shown (Aspinall, 1966) that Prior's early maturity is due to its photoperiodic response, following winter sowing, heading occurs soon after day length has reached 12 hours. At 35°S latitude anthesis in Prior takes place about October 1st (= April 1st Northern Hemisphere) two to three weeks ahead of the older European varieties (Sparrow 1972). Prior was rapidly accepted by farmers through-out southern Australia, and later also in Queensland, and provided the main basis for the Australian crop until the release of new varieties towards the end of the 1960's. During the 1920's a regular export of malting barley was

developed from South Australia and Victoria to Britain. In 1934 the Californian six-row variety Atlas was introduced into Western Australia to build up an export trade in that type of grain to compete with Californian exports. In the 1950's Beecher was introduced and released as a replacement and is only now being phased out. In Tasmania, with milder conditions, British varieties continued to be grown progressing, over the years, through Plumage-Archer to Proctor.

The first Australian bred variety, Research, was released in Victoria for the mild, southern areas of the State in 1941; it was selected by A. Raw from the cross Prior x Plumage-Archer. That programme was run part-time with a wheat programme and lapsed a few years later. During the 1940's a few other barley varieties were produced by wheat breeders but never became commercially important.

After 1945 world demand for coarse grains and malting barley increased enormously and the production and export of Australian barley developed rapidly. By the mid-1950's this now sizeable export trade was meeting stiffer competition in Europe following locally increased production as a result of improved agronomic techniques and crop varieties. At the same time the malting quality of Prior was declining as a result of a general increase in grain protein content. This can be attributed to the steady spread of subterranean clover and annual Medicago species and the adoption of ley farming in the cereal areas of southern Australia. Under the rotation barley-pasture-barley, which became common on many light soils, a steady increase in soil fertility occurred, a pattern that could be repeated as ley farming is adopted in the Mediterranean Region. As a result grain yields and grain protein contents increased; in addition, the increased area of barley meant a larger proportion of the crop was being grown in drier localities, all leading to a general decline in the malting quality of the crop.

The start of improvement programmes

It was these influences of expanding production, stiffer competition for exports and declining quality that stimulated the initiation of improvement programmes from the mid-1950's. These programmes have generally been financed by various sections of the barley industry, the farmers, the maltsters and brewers, and the marketing organisations backed by the Australian Government.

Australian barley programmes started with the minimum of locally adapted genetic resources. The only near land-race is a somewhat variable six-row variety called Cape, probably introduced from South Africa in the early days of settlement. Of necessity, therefore, the initial stages of all the programmes have been based on the established two-row variety, Prior. Although this variety was Australia's leading variety for nearly 70 years, it does have several undesirable characters. It can grow rather tall and with a long neck is inclined to severe head loss under sirocco conditions at harvest; it tends to respond to high fertility by excessive vegetative growth leading to increased transpiration loss and eventual moisture stress in spring during grain filling; its important attribute is its photoperiodic response and thus early maturity, the reason for its adaptation to a Mediterranean climate. The breeding programmes which started in the 1950's were all based on Prior crossed with a range of the then current European two-row varieties with the aim of combining the adaptation of the former with the agronomic attributes of the latter, namely short strong straw, responsiveness to improved fertility, increased yield and improved malting quality. The new Australian varieties such as Bussell (1967), Clipper (1968), Ketch (1970) and Lara (1971) display these agronomic attributes combined in a genotype adapted to southern Australia. They rapidly replaced the old variety Prior, and have been estimated to have increased average farm yields by 15-20%, whilst Clipper's improved malting quality has been happily accepted by the malting and brewing industry and is often specified by name in export orders.

The success of this wave of varieties illustrates an important point for barley improvement. In selecting parents for crossing it is unnecessary that all should perform well in the local environment. Varieties known to perform well in other environments can be a valuable source of genes for yield improvement (Sparrow 1966). The addition of a key character, such as early maturity, may transform an unadapted genotype into an adapted one. This suggests that a rapid method of variety improvement in the Mediterranean Region may be by the use of an inverted backcross system in which the high yielding exotic variety is used as a recurrent parent and a locally adapted variety as the donor with selection for the key character in the exotic background (McWhirter 1977). This approach has been used in the Texas Sorghum programme where African varieties have been 'converted' for

American conditions by the addition of genes for day neutrality and dwarfness (Stephens et al. 1967).

Genetic resources

The start of Australian barley breeding programmes was, naturally, followed by the introduction of many exotic varieties, both two and six row, and the testing of these for their suitability for Australian conditions or as parental material. Working at the Waite Institute in South Australia from1955 Dr.K.W.Finlay gathered together a collection of barley varieties and tested many of them over several sites and seasons. This lead to his interest in genotype x environment interaction and the development of the adaptation analysis (Finlay and Wilkinson 1963). The Waite Institute collection now contains about 3000 entries and hopefully will eventually be upgraded to become the Australian National Barley Collection. During this early stage of varietal assessment, it was found that several introductions from North Africa were well adapted to South Australian conditions and in diallel crosses exhibited high general combining ability. Physiological studies (Aspinall 1966) indicated that in contrast to Prior, or even varieties from Europe, those from North Africa were relatively insensitive to photoperiod. Two types of photosensitivity seem therefore to provide an adaptation to the latitude of the Mediterranean Region and southern Australia. The relative advantages of the two systems have not been compared but it should be pointed out that the wide adaptability of the Mexican wheats is attributed to their relative day length insensitivity.

Crosses involving the two-rowed Egyptian variety, CI3576, have segregated many high yielding lines with excellent field characters. The best parental combinations have been between this variety and various European varieties. Selections WI 2197, WI 2198 (Bonus x CI 3576) and WI2231 (Proctor x CI 3576) have all performed well in nurseries in the Mediterranean Region. Corvette (Bonus x CI 3576) is soon to be released as a feed grain variety in southern Queensland and WI 2231 could be released in South Australia. A further advance is now under way by bringing together in hybridization the two waves of improvement, Prior x European and North African x European, selections at advanced stages of testing are showing a yield increase over Clipper of the order of 10-15%. Some of these lines will be in the 1977 Preliminary Observation Nursery.

Any of the material derived from 20 years barley improvement in Australia could provide ready made varieties for the Mediterranean Region or excellent parent material for local programmes. The success of the Australian programmes illustrates an important principle of plant breeding that the wider the germplasm base for hybridization the greater the potential gain, a principle always stressed by CIMMYT and the other International Institutes.

Two-row versus Six-row

As mentioned earlier a large proportion of the Australian barley crop is of two-row varieties. This is due to tradition and also to the continuing world demand, both by maltsters and by the feed industry, for plump, even sized, two-row samples. It has been argued that the six-row character with a large head gives a greater potential for grain yield. I doubt the validity of this argument. The important yield character is not head size but grains/m^2. Within plant competition for assimilate results in internal compensations so that large heads or six-row heads are normally associated with reduced tillering. In barley the most important selection criterion is yield in the bag not yield in the eye, selecting for large heads could be a cul-de-sac.

The greater tillering capacity of two-row varieties is a useful attribute under a Mediterranean climate. In Australia seed rates for barley are only 30-50 kg/ha; with the tillering capacity of the new varieties this is sufficient to achieve adequate crop density. Under dryland conditions a dry winter can restrict tillering but, if followed by a wet spring, stimulate in two-row types a flush of late tillers, which if conditions remain favourable can rescue the crop. These conditions prevailed in South Australia in 1975 and 1976, production estimates in August (February) 1976 were 458,000 tonnes, in November (May) 711,000 tonnes but the actual harvest reached 950,000 tonnes.

Australian Barley Improvement Programmes

The senior programme in Australia is that based in the Agronomy Department of the Waite Agricultural Research Institute, South Australia. The programme was started in 1955 by Dr.K.W. Finlay, who was joined by the present author in 1960. A parallel programme of wheat improvement in the same department has been run since 1965 by Dr.A.J.Rathjen.

The Waite Institute is part of the University of Adelaide and staff are expected to engage in undergraduate and postgraduate teaching as well as research. Besides producing varieties our breeding programmes are used for teaching demonstrations, to provide problems for postgraduate investigations and as a test-bed for our own hypotheses. For example, in recent years several students have studied selection procedures and the efficiency of yield selection in early generations using current breeding material. Many aspects of the work receive a more fundamental backing from our colleagues in such disciplines as Biometry, Plant Pathology and Plant Physiology.

Notwithstanding the academic climate at the Waite Institute there has been a steady production of new varieties of barley and wheat. All the Waite Institute (WI) barley lines, together with Clipper, Ketch, Cutter and Corvette originate from this programme. This material as well as our postgraduates working overseas or returned to their own countries are making a useful contribution to the International development of Agriculture.

The main selection procedure adopted at the Waite Institute has been the F_2 progeny method (Lupton and Whitehouse 1957). This selection system concentrates on the yield of F_2 plant progenies over several generations at a range of sites leaving reselection for homozygous lines until F_5 or later. Progenies with poor straw strength or late maturity are discarded but yield is taken to be of greater importance than other plant characters. That some progenies are heterogeneous is unimportant as the initial unit of selection is more the cross than the progeny. This enables the crosses with the best yielding potential to be isolated so that reselection can be concentrated in the most profitable area, a necessity when a wide range of genetic material is under study. This system is the most efficient for a small team and avoids excessive hand labour, expensive in Australia, but its prime attribute is that selection is concentrated on the objectivity of yield although undoubtedly the experienced judgement of the breeder continues to play an important part in selection.

The general trend of the breeding programme in exploiting the recombination of Australian, European and North African varieties has been covered in the selection above on genetic resources. Although two-way crosses between adapted and exotic varieties were common in the early stages of the programme it has, in recent years,

been found more useful to backcross such an initial cross to the same or another adapted parent. Intercrossing between our own selections is also important. Some recent crossing programmes have been concerned to further reduce straw height and increase straw strength in adapted material. In barley, straw strength need not be directly related to stiffness. The best type of strength is available in the resilient straw of many European and recent Australian two-row varieties. The stiff Japanese and Canadian six-row varieties tend to become very brittle under dry conditions. Resilience of straw and resistance to shattering in areas with sirocco conditions at harvest could be more important than resistance to lodging alone. Dwarfness is available in several varieties and mutants but is generally linked with lateness. We may have broken this linkage in crosses, now in F_4 involving Abed Deba and Diamant as sources of dwarfness. We are also looking at the possibilities of Indian Dwarf, XV 2552 (INIA, Mexico), M22 (Minnesota), Golden Promise and Midas as parents for shorter straw height. Like the Norin 10 semi dwarf wheats, dwarf barleys in Europe have provided an additional increase in yield, whether this will be so in a Mediterranean climate is still to be determined. A recent report from South Africa indicates that under irrigation in the Western Cape, which has a Mediterranean climate, Clipper is outyielded by Diamant, Midas and some Maris Mink derivatives (Eisenberg pers. comm.). Here the interaction of lateness and irrigation may have been important. Under dryland conditions with severe moisture stress height is reduced in any case, what has to be determined is whether dwarf varieties would become too short for available harvesting equipment.

The programme at the Waite Institute has always been concerned with selection for good malting quality because much of Australia's barley is exported on this basis. More recently we have also been interested in improving the feeding quality of barley. There is an assumption that barley for feed needs to be high in protein. Unfortunately there tends to be an inverse correlation between grain yield and protein content. However, differences in grain protein are greater for environmental than for genetic variation (Sparrow 1972), an increase in soil fertility is likely to lead to an increase in grain protein content. It is suggested that it would be better to concentrate on improvement in protein quality through the introduction of high lysine types and leave increased soil fertility to improve protein quality. It has been relatively easy to transfer the Hiproly gene for high lysine into varieties of

acceptable agronomic type adapted to southern Australia, but the inherently greater variability in the first lines selected is probably a function of grain shrivelling (Table 4). More recent selections are expected to show an improvement in this character. This programme would have been more difficult without the help of a colleague, Dr. K. Shepherd, who has been able to turn his expertise in protein characterisation to the detection of the Hiproly gene by starch gel electrophoresis. Dr. R. Oram of C.S.I.R.O., Plant Industry, Canberra, has been attempting to transfer the Risø 1508 high lysine gene to adapted material with a plump grain. He has not so far overcome the grain shrivelling problem.

In the Department of Plant Physiology work has been under way for several years to elucidate the metabolic basis for resistance to environmental stress, particularly moisture stress. The ability of plants to accumulate proline when subjected to moisture stress has been suggested as a possible index for selecting drought resistant barley varieties. In pot experiments ten barley varieties accumulated free proline at different rates when stressed (Singh et al. 1972). The free proline content after stress was highly correlated ($r = 0.89^{**}$) with the stability index of the same varieties calculated by Finlay and Wilkinson (1963) who suggested that water availability was the most important limiting factor in their series of trials. There was also a correlation between maturity and proline accumulation ($r = 0.71^{**}$). The relation between earliness and drought resistance is well documented (Levitt 1972) and earliness was considered to be an important character in increased genotype stability in the above trials. Even when the effect of maturity was removed the partial correlation between proline and stability was still significant ($r = 0.74^{**}$).

The possible use of proline accumulation as a criterion in the selection of drought resistant barleys has been under investigation by a postgraduate student, (Lewin and Sparrow 1975). His work has emphasized the complexity of drought resistance which may be due to several factors singly or in combination. Apparent resistance may be associated with escape (by early maturity), avoidance (by efficient root systems or better stomatal control) or with tolerance (ability to resist desiccation). Proline accumulation is related to the last factor. Lewin suggests that in the improvement of drought resistance escape and avoidance should be exploited first. Since there is evidence that the ability to accumulate proline is related to stress resistance and because

there is sufficient genetic variability in this character it could be useful in selection. There are still some technical problems to be overcome but a simple, non-destructive, test for drought resistance could be extremely useful in selection for barley varieties adapted to Mediterranean dryland agriculture, (Lewin et al. 1977).

Barley diseases are not a major limiting factor to the Australian crop but varieties resistant to two or three diseases could help stabilise production. In southern Australia Cereal Cyst Nematode (Heterodera avenae) is widespread, attacks wheat, oats and barley, and in severe infestations can cause localized crop failure. Barley is more tolerant than the other two species, and we have located several sources of resistance in North African varieties. Resistance genes are being transferred to Australian varieties and rapid laboratory tests for resistance have been developed to aid selection (C.O'Brian 1976, Brown et al. 1977). Breeding for resistance to the other important barley disease in southern Australia, Barley Leaf Scald (Rhynchosporium secale), is likely to be much more difficult. A collaborative research project investigating crop loss assessment, pathogenic variability, sources of resistance and mechanisms of resistance is being conducted by plant pathologists and plant breeders in the Universities of Adelaide and Western Australia and the South Australian and Western Australian State Department of Agriculture. Although sources of resistance are available and are being transferred to locally adapted varieties by backcrossing corresponding virulent strains of the pathogen have been isolated even though the resistant varieties have not been grown commercially in Australia (Ali et al. 1976). The pathogen also attacks barley grass (Hordeum leporinum) which is widespread and may be the primary source of infection and pathogenic variability. Varieties with multiple gene resistance or multiline varieties could be the answer to this problem. Powdery Mildew of Barley (Erysiphe graminis) is only occasionally severe in southern Australia where warm dry spring weather limits its spread at the critical grain filling period. It can be a problem in Queensland where more humid conditions prevail. Breeding for resistance in that area is only just starting but some work has been carried out on fungicidal control.

The plant breeders at the Waite Institute have also developed special machinery for field plot work as well as computer programmes for handling plant breeding data. These developments are aimed at improving the efficiency of our operations and reducing the labour requirement of the programmes. Also at the Institute there are more fundamental studies on such topics as barley haploids, inter-

relationship of Hordeum species, the development of wheat: barley hybrids and the physiology of the barley plant and germinating grain. Thus the Waite Institute is an active centre for research on barley, and the problems and potential of the crop in dryland Mediterranean agriculture.

There are also barley improvement programmes elsewhere in Australia. In Western Australia the joint breeding programme of the University and State Department of Agriculture concentrates on selection for high yielding, large grained feed barleys after their success with the variety Dampier. Unlike other programmes in Australia they select both two and six row types. At the University Dr. W. J. R. Boyd has studied the genetics of resistance to several barley diseases and collaborates in the investigations on Barley Leaf Scald mentioned above.

Barley improvement in Victoria like South Australia is chiefly concerned with malting barley and is divided into a northern and southern programme to serve the needs of two rather different environments. The drier northern area borders South Australia and growing conditions are somewhat similar except that winter temperatures are lower and soil type in part of the area, the Wimmera, is heavier and more fertile. The southern area has a higher rainfall and milder climate than any other part of the cereal belt of mainland Australia. It produces prime malting barley and is conveniently near Melbourne where the main malting capacity is situated. Varieties from this area, such as Research or Lara are intermediate, between Mediterranean and European types and could be useful in the higher rainfall areas of the Region. The Victorian programme, which is run by the State Department of Agriculture, is particularly strong in agronomic studies of barley growing and in grain quality testing.

Currently there is no barley breeding in New South Wales but barley is a useful crop in the Riverina areas in the south of the State with an outlet through Melbourne. The Agricultural Research Institute at Wagga Wagga has been screening varieties for local suitability.

In Queensland, Dr. R. P. Johnston, at the Hermitage Research Station near Warwick has recently started a hybridization and selection programme although he has been variety testing for several

years and was instrumental in the release and recommendation of Clipper and Corvette in that State. Queensland barley growing areas are environmentally different to those in southern Australia and the fact that the new South Australian varieties have performed so well is indicative of their wide adaptability, some European varieties such as Zephyr and Maris Baldric also perform quite well, but recent local selections have outyielded both groups in preliminary trials. This raises the question as to whether centralized selection for wide adaptability although demonstrably successful in wheat and rice is necessarily the ultimate in yield improvement for particular areas.

Tasmania grows less than 1% of the total Australian barley area and all the grain is used on the island. The English variety Proctor is the only variety grown. In trials European varieties perform well but the local malting and brewing industry is particularly concerned to maintain quality thus restricting the release of new varieties. The most important problem is the high incidence of Barley Yellow Dwarf Virus and the State cereal breeder is about to release a virus resistant Proctor produced by backcrossing to an Ethiopean source of resistance. This selection has, in areas of severe disease, shownyield increases above Proctor of up to 300%.

Lack of space has restricted a detailed consideration of the Australian barley improvement programmes other than in South Australia. There is however a good deal of integration between the programmes with good cooperation and interchange of material and information. The amount of breeding material being handled in Victoria and Western Australia is similar to that in South Australia.

SUMMARY

Over the past 20 years there has been a considerable development in research aimed to improve the Australian barley crop, the return to the grower and processor through improved agronomy and new varieties has been marked. Further improvements will undoubtedly come over the next decade. Many of these improvements are readily applicable to the climatically similar countries of the Mediterranean Region. Australian barley varieties could find an immediate place in some areas whilst such varieties and other breeding material could be used as parents in local programmes. Much Australian research on barley could be translated to Mediterranean conditions and some postgraduates from the Region are already being trained in Australia.

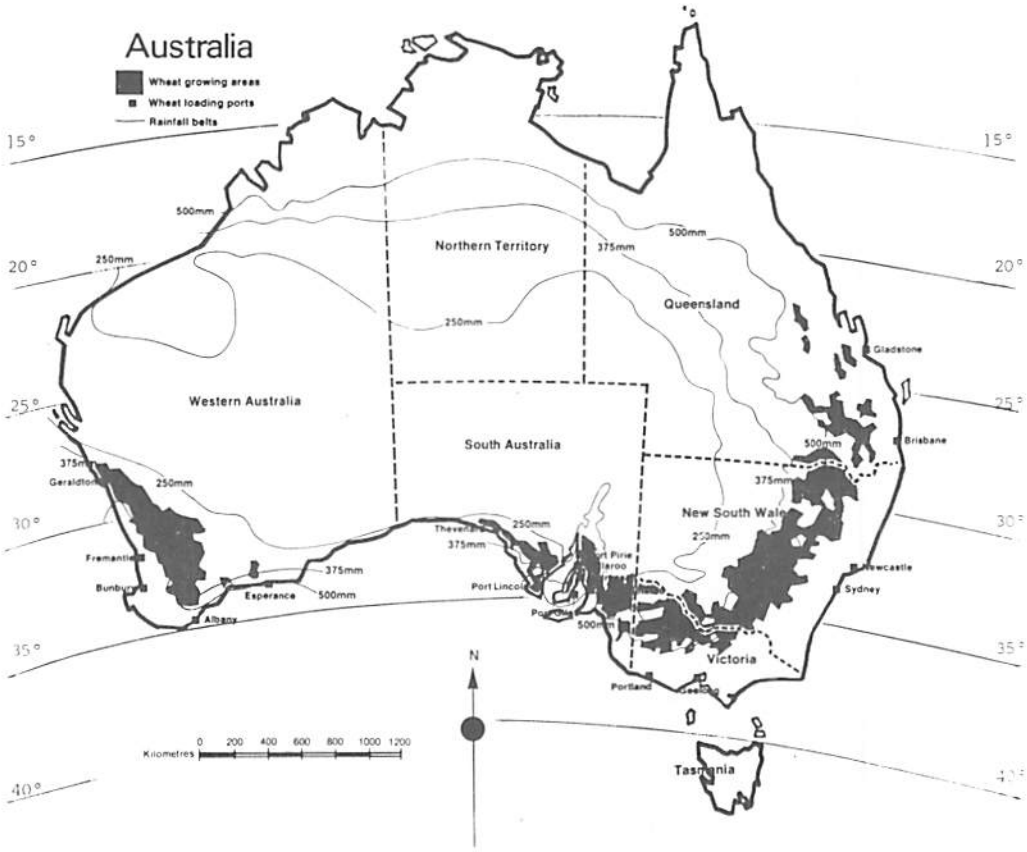

Figure 1. Australian Cereal growing areas (from Australian Wheat Board Report 1974-75)

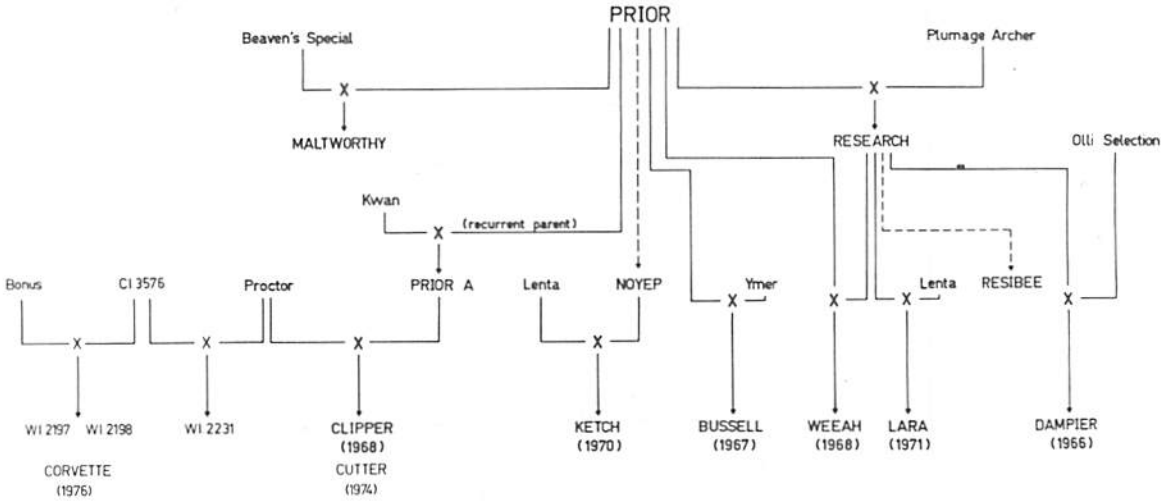

Fig.2 Pedigree of Australian Barley Varieties.

TABLE 1

Barley trials results in tonnes/ha for 4 varieties over 4 years at 4 sites in South Australia

	1965				1966				1967				1968				VARIETY MEAN
	B	C	M	W	B	C	M	W	B	C	M	W	B	C	M	W	
CI:3576	2.48	1.61	1.33	1.82	2.04	2.26	1.57	3.69	1.11	0.82	2.39	1.24	2.45	2.23	2.57	3.52	2.07
Prior	1.20	1.22	1.53	1.21	1.28	1.60	0.99	3.08	1.14	1.49	1.28	0.86	1.52	1.79	1.77	2.48	1.47
Clipper	1.97	1.10	2.09	1.22	1.62	1.93	2.46	3.91	1.31	0.12	1.99	0.48	2.32	2.26	2.78	4.11	1.98
Ketch	2.31	1.70	2.73	2.11	1.77	1.90	1.21	3.00	1.12	0.83	2.44	1.07	1.92	2.07	2.23	3.60	2.00
Site Mean	1.99	1.41	1.92	1.59	1.68	1.92	1.56	3.42	1.17	0.57	2.03	0.91	2.05	2.09	2.34	3.43	
Year Mean	1.73				2.15				1.17				2.48				

TABLE 2

Five year averages of Australian wheat and barley areas.

Seasons	Area of wheat ,000 hectares	Area of barley ,000 hectares	Barley area as a percentage of wheat area
1945-46 1949-50	5,124	351	6.9
1950-51 1954-55	4,345	572	13.2
1955-56 1959-60	4,003	880	22.0
1960-61 1964-65	6,396	916	14.3
1965-66 1969-70	8,986	1,172	13.0
1970-71 1974-75	7,695	2,079	27.0

TABLE 3

Distribution of Australian barley crop by State averaged over five seasons 1970-71 to 1974-75

	Area ,000 hectares	Percentage of crop
Queensland	125	6.0
New South Wales	345	16.6
Victoria	261	12.5
South Australia	699	33.6
Western Australia	637	30.6
Tasmania	12	.6
Total	2,079	

TABLE 4

Yields, as % of Clipper of high lysine selections in small scale trials and grain analyses of two bulk samples.

	1973				1974				1974 Bulks from Waite Inst.		1975 Bulks from Turretfield	
VARIETIES / SITES	BUNDALEER	CLINTON	MINLATON	WAITE INST.	CLINTON	WAITE INST.	ROSEWORTHY	OVERALL MEAN FOR SEVEN SITES	PROTEIN %	LYSINE AS % OF PROTEIN	PROTEIN %	LYSINE AS % OF PROTEIN
Clipper (t/ha)	100 (2.80)	100 (1.98)	100 (3.64)	100 (2.56)	100 (3.03)	100 (2.97)	100 (3.46)	100 (2.92)	-	-	-	-
WI.2231	106	107	117	138	167	127	102	123	9.3	2.93	12.7	3.3
HCB 27/1/13	75	52	96	87	78	94	70	79	11.1	3.71	13.5	4.1
HCB 27/1/14	101	98	97	115	94	79	111	99	12.1	3.43	-	-
HCB 38/1/5 (naked)	45	42	99	89	90	60	80	72	14.3	3.44	16.3	3.8

REFERENCES

ALI, S.M., MAYFIELD, A.H. and CLARE, B.G. (1976) - Pathogenecity of 203 isolates of Rhyncosporium secalis in 21 barley cultivars. Physiological Plant Pathology 9 : 135-143.

ASPINALL, D. (1966) - Effects of day length and light intensity on growth of barley. IV Genetically controlled variation in response to photoperiod. Aust. J. biol. Sci. 19 : 517-34.

BORLAUG, N.E. (1968) - Wheat breeding and its impact on World food supply. Proc. 3rd Int. Wheat Genetics Symp. 1-36. Canberra Aug. 1968.

BROWN, J.A.M., ELLIS, S.E. and MULLALY, J.V. (1977) - Breeding for resistance against Cereal Cyst Nematode in Australia. Proc. 3rd Int. Congr. SABRAO 4(b) 32-33. Canberra Feb. 1977.

BYTH, D.E. (1977) - A conceptual basis for G x E interactions for plant improvement. Proc. 3rd Int. Congr. SABRAO 3(d) 1-11. Canberra Feb. 1977.

CORNISH, E.A. (1949) - Yield trends in the wheat belt of South Australia during 1896-1941. Aust. J. Sci. Res. B. 2 : 83-137.

CORNISH, E.A. (1950) - The influence of rainfall on the yield of wheat in South Australia. Aust. J. Sci. Res. B. 3 : 178-218.

EBERHART, S.A. and RUSSELL, W.A. (1966) - Stability parameters for comparing varieties. Crop Sci. 6 : 36-40.

EISEMANN, R.A., BYTH, D.E., DeLACY, I.H. and TAYLOR, P.J. (1977) A comparison of some methods of analysis of G x E interactions and adaptation responses in a large data set. Proc. 3rd Int. Congr. SABRAO. 3(d) 41-46. Canberra Feb. 1977.

FINLAY, K.W. and WILKINSON, G.N. (1963) - The analysis of adaptation in a plant breeding programme. Aust. J. agric. Res. 14: 742-54.

FRANKEL, O.H. (1958) - The dynamics of plant breeding. J. Aust. Inst. agric. Sci. 24: 112-23.

FREEMAN, G.H. (1973) - Statistical methods for the analysis of genotype environment interactions. Heredity 31: 339-534.

KNIGHT, R. (1970) - The measurement and interpretation of genotype environment interactions. Euphytica 19: 225-235.

LEVITT, J. (1972) - Response of plants to environmental stress. Academic Press, New York and London.

LEWIN, L.G. and SPARROW, D.H.B. (1975) - The genetics and physiology of resistance to stress. Proc. 3rd Int. Barley Genetics Symp. 486-501. Garching July 1975.

LEWIN, L.G. SPARROW, D.H.B. and ASPINALL, D. (1977) - Proline accumulation and drought resistance in barley. Proc. 3rd Int. Congr. SABRAO. 3(b) 8-12. Canberra, Feb. 1977.

LUPTON, F.G.H. and WHITEHOUSE, R.N.H. (1957) - Studies on the breeding of self pollinating cereals.I Selection methods in breeding for yield. Euphytica 6 : 169-184.

McWHIRTER, K.S. (1977) - Utilization of genetic variability in autogamous plant species. Proc. 3rd. Int. Congr. SABRAO. 2(c) 1-9.

MUNGOMERY, V.E., SHORTER, R. and BYTH, D.E. (1974) - Genotype x Environment interactions and environmental adaption I Pattern analysis-application to Soyabean populations. Aust. J. agric. Res. 25: 59-72.

O'BRIEN, P.C. (1976) - Studies on the relation of Heterodera avenae to cereals. Ph.D. Thesis, University of Adelaide.

PEDERSON, D.G. and SEIF, E. (1975) - Compensating for site and year effects in estimating the true yield of wheat genotypes. Aust. J. agric. Res. 26 : 783-90.

PERKINS, J.M. and JINKS, J.L. (1968) - Environmental and genotype-environmental components of variability III Multiple lines and crosses. Heredity 23 : 339-356.

SINGH, T.N., ASPINALL, D. and PALEG, L.G. (1972) - Proline accumulation and varietal adaptability to drought in Barley. Nature New Biol. 236 : 188-190.

SPARROW, D.H.B. (1966) - Selection for adaptability in a barley breeding programme. Proc. Aust. Cereal and Pasture Plant Breeding Conf. 3, 6-8. Brisbane, Aug. 1966.

SPARROW, D.H.B. (1972) - A study of genotypic differences in the malting quality of barley. Ph.D. Thesis, University of Adelaide.

SPARROW, D.H.B. and DOOLETTE, J.B. (1975). Barley in "Australian Field Crops I Wheat and other temperate cereals". 431-450. Edited by Lazenby, A. and Matheson, E.M. (Angus and Robertson, Sydney).

STEPHENS, J.C., Miller, F.R. and ROSENOW, D.T. (1967) - Conversion of alien Sorghums to early combine genotypes. Crop Sci. 7 : 396a.

BREEDING FOR WIDE ADAPTABILITY AND SUPERIOR AGRONOMIC TYPES IN BARLEY

By

Dr. Enrique Rodriquez Campos *

Breeding for Wide Adaptability

Barley is one of the oldest among the cultivated cereals, being found in archaeological remains of the earliest civilizations (1). It is probably one of the most widely adapted cereals. It can grow from the North Pole to the Equator- on poor alkali soils and under very dry conditions. Some barley varieties are more cold tolerant and can grow further away from the Equator than any other cereals. Within the barley species one can find a very large number of types easily differentiated from one another by their appearance.

Yet despite all these remarkable characteristics of barley, the adaptation of individual varieties has been somewhat limited and generally they are adapted to very specific areas. The adaptation becomes more limited as these varieties are moved latitudinally.

What makes varieties of other cereals such as wheat thrive at different latitudes ? First, we must remember that wheat is a hexaploid species (2n=42), whereas cultivated barley is a diploid (2n=14). This has a marked influence on the behaviour of the individual varieties. Wheat, with the larger number of chromosomes has the ability to buffer the crop against changes in latitude, and changes that take place between different environments.

One of the major disadvantages of barley with respect to other cereals is its sensitivity. This character is reflected even in the early maturing types, and is one of the major causes of the narrow adaptation of barley. We have seen for example, in the variety Early Russia, one of the earliest types with which we have worked that when it is grown near Mexico City at latitude 19°31'N, the time to heading is approximately 40 days whereas in the same variety grown at Cd. Obregon, Sonora at latitude 27°29'N, heading begins at 50 days. If we examine the time to heading of some other varieties grown at these two different latitudes, the difference is even greater

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(see Table 1). The result is that certain varieties may or may not fit the growing period in a particular region. There are also some differences in temperature between the two locations during the growing cycle which can also contribute to these differences in heading times (see Table 2). Photoperiod sensitivity and temperature are not the only factors affecting adaptation. Disease insects, soil and general environmental conditions also play an important role in the adaptability of a variety (2).

Adaptation, it may be seen, is indeed a very loose term and cannot be defined simply. Actually, more than a character per se, it is the end result of a series of characters. It can be measured indirectly, the yield of grain of the particular variety over a large number of locations, being the best gauge (3).

In the CIMMYT Program one of our major concerns is the breeding of varieties with a wide range of adaptation. Following the steps of a pattern already established by the CIMMYT Wheat Program, we have been trying to select such types. By growing the crop in Mexico, one automatically screens for photoperiod insensitivity since varieties which are sensitive are very late in flowering at this latitude. By growing two alternate generations a year at two different locations we have been able to increase adaptation. The two locations offer different sets of conditions. One is located near Mexico city at an altitude of 2,249 MASL. For the most part, the crop at this location is rainfed with generally overcast skies and conditions during the growing cycle which favours the development of several diseases. The other location is in Sonora, Mexico at 38 MASL at a latitude of 27°29'N. Here the crop is grown exclusively under irrigation in a desert climate, and with the exception of stem rust and leaf rust which appear late in the season, the disease problem is almost nil. It must be pointed out that this latter site offers ideal conditions, for the plant to express its maximum yield potential if adequate straw strength is bred into the varieties. The material is screened, selected, and yield tested under these conditions. The materials that prove to be high yielders at these two locations are later distributed in the form of nurseries to several cooperators around the world. The data received are analyzed and summarized. The number of locations at which a particular line yielded well give a good indication of its adaptability. To illustrate this, some lines from the first Elite Barley Yield Trial (EBYT) are included in Table (3). The fact that the cross CM67-Mona appears among the top 5 in 10 of 17 locations, clearly indicates that the cross has a wide range of adaptation. It is interesting to note that this cross involves two parents which are photoperiod insensitive. These data are very valuable

in a breeding program, for they offer a means of locating "model genotypes" which can be used for further improvement (disease resistance, quality, etc) to maintain yield stability.

Breeding for Super Agronomic Types

It has been stated that the term adaptation is difficult to define. It is no easier to find a definition for "superior agronomic type". Again rather than being a single character it is a series of features that contribute to the formation of a particular genotype. But again, these individual characters can be measured independently using different scales.

From a breeder's standpoint the measurement of certain parameters is of little kmportance, especially when a large number of crosses are being handled each breeder tends to have in mind certain ideal characteristics of the perfect plant, an ideotype, when looking for the superior agronomic type.

There are, however, certain characters of the plant that may be used as guidelines in the search for a superior agronomic type. Among these we can name the following:

1. Good tillering capacity.
2. Resistance to lodging.
3. Disease resistance.
4. Good spike development.

As we can see these features describe very well wheat a superior agronomic plant might possess. They are, however, very general concepts, and each one of these features has to be further defined. It is instructive to analyze each of these concepts individually.

a) Good tillering capacity. What is a plant with good tillering capacity ? This of course is relative. The number of tillers can vary from the uniculm to 50 or more tillers per plant depending upon the conditions. The number of tillers is also affected by the type of barley variety. In general a two-row barley tillers more than a six-row, this in turn is affected by the rate of seeding used but in a thin stand this statement is decidedly true. It should be stated that a high tillering capacity does not necessarily mean high number of heads. With high seeding rates, the competition for nutrients and light is such that many tillers die before they reach the head-bearing stage.

b) Resistance to lodging. Londing in barley is generally caused by two factors:

1) The lack of a well-anchored crown which can stand the weight of the aerial part of the plant.

2) The lack of a strong straw which can stand the weight of the head.

These two factors are independent, and both of them must be present in a lodging-resistant plant. This includes dwarf plants as well.

c) Disease resistance. Under this general heading we include not only disorders caused by micro-organisms but also any other factor (genetically or environmentally induced) which can disturb the normal development of the plant (chlorosis, necrotic spotting, leaf firing, head trapping, etc.)

d) Good spike development. The evaluation of this character as in the others, is made visually by observing the number of spikeletd and their fertility. The number of spikelets varies according to the type of barley (2 row vs. 6 row). In general the 6 row types produce more fertile spikelets than the two rowed. Further, a large head does not necessarily mean a large number of spikelets. The head must be attached to a strong neck to prevent neck breaking and its rachis must be strong enough to prevent shattering.

An agronomic type with the characteristics described is not necessarily a high yielding type. There are other factors such as grain size and test weight of the grain which can influence yield. This should be assessed later. Examples of superior agronomic types which were selected using the above criteria are listed in Table (4).

In practice most of the features mentioned above are generally determined by the breeder empirically "by the looks" of the plant.

Following are some hints that can be useful when one is searching for the superior agronomic type:

1. The nursery where the selection is to be made, must be given the best cultural practices within the resources of the area, so that the genotype can express itself to its maximum capacity.

2. Variation within the population must exist, so that differences can be established more easily. It is very difficult to identify superior agronomic types in a homogeneous population.

3. The plants should be space-planted in order that they may show their maximum phenotypic expression.

4. Check rows of high yielding commercial varieties should be included for comparison purposes.

5. The degree to which desirable genes are present either homozigously or heterozygously within a plant is greatest at F_2 so that selection for good agronomic type should be made at that generation. In succeeding generations the statistical probability of the desirable genes being present falls off very rapidly.

Limitations in Breeding for Superior Agronomic Types:

In breeding for superior agronomic types, certain factors must be taken into account:

1. There are many poor agronomic genotypes with which it is difficult to work. Some of them have very specific combining ability, and many of them inherit their bad features in a block (probably very closely linked genes). Multiple crossing which includes several doses of good agronomic types must be made, if one is to select superior agronomic types from these. For example in a cross of a tall variety by a short with dominances for tall height, the segregates of a single cross such as this will be predominantly tall and the few short segregates will only marginally sample the genetic variation of the cross. In a double cross, however, with three short types and one tall type, a large number of short plants will segregate and variability among them is tremendously greater than that resulting from the single cross.

2. When working with early types it is nearly impossible to breed for superior agronomic types with high tillering capacity and large heads. Our experience has shown only limited success and then only to a certain degree. Undoubtedly, this arises from the fact that the plant has only a certain capacity to absorb and assimilate nutrients in the given short length of time.

To conclude, I must say that the concepts mentioned above are drawn from my personal experience and no pretence is made that this is the only viable approach. It appears, however, to yield very useful results. Plant breeding continues to be largely an art which involves a basic knowledge of the crop combined with a good level of common sense. We believe that a program conducted on a large scale is as yet the way to

greatest returns. CIMMYT is fortunate in having close relations with the breeding programs of many countries and though our joint efforts I am sure we will produce new widely adapted barley varieties capable of providing increased levels of food for the increasing population.

Literature cited

(1) Wiebe, G.A. 1968.
Barley: Origin, botany, culture, winterhardiness, genetics, utilization, pests. USDA, ARS Agriculture handbook No. 338.

(2) Krull, C.F., N.E. Borlaug, C.Meza, I.Narvaez, 1968.
Results of the First International Spring Wheat Yield Nursery 1964-1965. CIMMYT Research Bulletin No.8.

(3) Finlay, K.W. and G.N.Wilkinson, 1963.
The analysis of adaptation in a plant breeding programme. Aust. J. Agric. Res. 742-54.

Table 1. A comparison of the days to heading of different lines and varieties of barley grown at two different latitudes.

Variety or line	Day to heading	
	Cd. Obregon, Son.	El Batan, Me
Puebla	90	56
Mezquite	97	56
Guajillo	99	65
Apam-IB65 x Gva	90	56
Arivat	89	55
Beecher	93	55
Athenais	88	78
Steptoe	121	73
Atlas 57	95	66

Table 2. Comparative mean temperatures during the growing cycle at Cd. Obregon, Sonora and El Batan, Mexico

Cd. Obregon, Sonora			El Batan, Mexico		
Month	Max	Min	Month	Max	Min
November	28.9	11.8	May	27.3	8.26
December	24.8	8.8	June	24.3	9.23
January	23.4	6.8	July	23.1	9.23
February	24.8	6.9	August	22.8	8.46
March	27.4	8.3	September	23.6	8.60
April	31.4	10.8	October	22.7	7.03

Table 3. Comparative results of selected lines from the 2nd Elite Barley Yield Trial

Entry name	No. of times in which the line was among the top 5	Number of locations
CM 67-Mona	10	17
Zephyr	7	17
Tequila	5	17
local check	5	17

Table 4. Comparative yields of superior agronomic types of barleys to assess yield potential in Cd. Obregon, Sonora, Mexico

Variety or line	Kgs/ha
Por-U.Sask 1766	7711
Tequila	7251
Arivat	5258
Masurka	5233
Manker	5993
Puebla	6805

OBTAINING GREATER PROGRESS IN BARLEY BREEDING

Donald C. Rasmusson*

All barley breeding programs can be improved. But each program is different from every other program and this makes it difficult to suggest useful ways of achieving greater progress. With this in mind, I have elected to rely heavily on my own experience as a basis for choosing topics with the hope that we share some of the same problems and hence that what I say will be appropos to breeding programs that many of you are conducting.

Topics that I will consider can be viewed in the context of decisions that each breeder must make. The first important decision or set of decisions that a breeder makes has to do with what research to emphasize and what characters to concentrate on. A second set of decisions relates to breeding methods - which methods to use and how to obtain good progress with these methods. My intent is to identify several important matters that fall within the framework of these two sets of decisions and then to offer suggestions that hopefully will lead to obtaining greater progress in barley breeding.

Making Decisions About What Research to do and What Characters to Emphasize.

A barley breeder frequently has several choices open to him relative to what research to do. Some barley researchers should do basic research, and research related to improving procedures and techniques. Examples of such research are familiar to all of you. Studies of the reasons for genetic incompatibility in wide crosses, and plant-modeling as it relates to energy capture are of interest. Studies are needed on breeding methods such as the haploid procedure for obtaining "instant" inbreds and on methods of producing barley hybrids. Likewise, research is needed on the possible advantages of male sterile facilitated recombination and on alternative methods of disease breeding. Success in breeding frequently depends on good screening techniques and a breeder may desire or even be required to research techniques.

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The research mentioned above is important, but it competes for time with variety development. My guess is that some barley breeders who are expected to devote full-time to developing varieties, divide their time between breeding and related research, and others may emphasize related research almost to the exclusion of breeding. Some barley breeders likely feel the need to do what others are doing or to get on the bandwagon, and hence involve themselves in research which may be inappropriate in their circumstance.

We know a lot about breeding varieties. One way to achieve greater progress in barley breeding is to put this information to work, i.e. to work at the job of breeding. In many situations breeding will be the most exciting and also the most rewarding of the alternative kinds of research that are possible.

Choice of Characters - High priority should be given to planning in all phases of a program and on a continuing basis. One important consideration is the choice of characters which will receive attention and their relative emphasis. What is most important --- a more dependable crop, higher potential yield, or improved nutritional and/or feeding quality? Sometimes this is a hard choice to make, especially in a developing country when emphasis may be on food, rather than feed- a dependable as well as a nutritious crop may be very important. It is a truism that progress per character is slowed as more characters are added to the list of breeding objectives, and it is likely true that many breeders are giving emphasis to too many characters, or giving characters equal emphasis when they deserve different emphasis. Also, it is true that for some characters (yield is an example), good progress isn't likely unless the breeding effort is sizable. So, it is essential that character choices be made with great care.

If yield breeding has high priority, some crosses ought to be made in hopes of achieving transgressive segregation for yield while ignoring all other attributes that are needed in a new variety. Ultimately, combination breeding or selecting parents that complement each other is essential, but it can come later.

Diseases sometimes are emphasized to the exclusion of other characters. Every cross that is conceived may emphasize disease resistance, and introduction of new germplasm may mean new sources of disease resistance. In this situation, there is a good likelihood of progress in breeding for disease resistance. This breeder should be satisfied that diseases warrant such high priority to the exclusion of other characters.

I suggest that the characters in a breeding program be examined on a continuing basis with the intent of keeping the number small, and the emphasis on those characters deemed most important. Disease breeding dominated my barley program for several years and I essentially neglected yield breeding. Looking back it is clear that I should have given much more emphasis to yield breeding.

Deciding on Breeding Methods

Most new barley varieties trace to introductions or to pedigree or bulk selection following hybridization. Backcrossing, a fourth method, are important, but at present not in the same class with introduction, pedigree and bulk breeding.

Introduction should play an even more important role in the years ahead. Barley breeders should not hesitate to utilize new varieties or parental germplasms or both from other breeders. I fully appreciate that it is hard to get credit for work done with an introduced variety, but the potential benefits to the country should come first. If direct utilization of introduced varieties is not possible, there are opportunities in utilizing the disease resistance, high yield, and/or lodging resistance that is present in introduced varieties or lines. The opportunities that already exist in utilizing introduced varieties will increase as genes for photoperiod insensitivity are incorporated into barley germplasm.

The pedigree and bulk methods differ in how and when selection is imposed and in how populations are advanced from one generation to the next. In the typical pedigree program, selection is practiced in each generation with selected families and plants contributing progenies to the next generation. In the typical bulk method, such selection is delayed until later generations at which time selection in the bulk method closely parallels selection in the pedigree method.

When selection opportunities exist in each generation, the pedigree method would appear to be most advantageous. On the other hand, when resources are limited and selection opportunities are nonexistent or modest, the bulk method may be at a relative advantage.

The pedigree method is the most commonly used method. Even so, it is often criticized as being inefficient. Some say it is wasteful of resources because of the expense of working with individual plants and the large amount of time spent on record keeping.

The manner of conducting the pedigree method varies from program to program and this is as it should be because circumstances vary. Nonetheless, it is a good idea to look for ways to make improvements in the method. Many breeders believe they have increased their effectiveness by omitting space planting altogether, practicing selection only on families. Some keep almost no records, or only a modest one.

Speeding up the Process - Every barley breeder should search for ways of reducing the time required to develop a new variety. Each year's delay in getting a new variety to growers can result in a substantial loss in production. The textbook example of 10-15 years is unacceptable in most circumstances. I have two suggestions to make that can lead to shortening the time that is required. The first is to grow more than one generation per year and the second is to speed up the process of variety development by eliminating some of the steps.

It has become a common practice in some breeding programs to grow more than one generation in each year, but in other programs, the opportunity may exist, but is not being utilized. Breeders in cold short-season climates may be able to arrange for a winter nursery in a warmer climate, while breeders located in warmer climates may be able to accommodate 2 crops per year. In Davis, California, for example, the primary barley breeding nursery is planted in late-fall and harvested in late-spring, and a secondary nursery can be planted following harvest of the winter-spring nursery. It is harvested in the fall. To be sure, the summer nursery requires special attention and growth is not optimal, but generation advance, seed increase, and some selection can be accomplished.

Some breeders find it highly advantageous to utilize greenhouses in the winter months to advance generations. We routinely obtain three generations in our most elite breeding populations per year in our Minnesota barley program. A typical first year procedure involves making crosses in a fall greenhouse, growing the F_1's in a winter greenhouse, and growing the F_2's in the field in the summer nursery. The second year starts in the fall greenhouse where we grow the F_3 generation. The F_4 generation is grown in the winter greenhouse and the F_5 generation in the field in the summer. In advancing from F_2 to F_3 and from F_3 to F_4, we use the single seed advance procedure. Each F_5 line thus traces to an individual F_2 plant. This procedure has important advantages. First of all, we have F_5 lines in the field within two years. Furthermore, selection among the F_5 lines that are relatively uniform is more effective than would be the case in selecting among F_3 lines. Expected additive genetic variance is significantly higher among F_5 lines advanced in this way than it is among F_3 families.

A second advantage is that the F_5 line is sufficiently uniform so that the seed can be bulked for yield testing. I should emphasize, however, that the single seed advance procedure probably has little place in the field when selection is possible.

In some circumstances, greater breeding progress could be achieved by reducing the number of generations that are employed when doing pedigree and bulk breeding. If selection is effective for critical traits in F_2 or F_3 or if no useful selection is possible, final plant selection (before bulking) might be done in the F_3 or F_4 generation. A variety tracing to an F_3 or F_4 plant would be relatively heterogenous, but there is little evidence to support the notion that a variety needs to be genetically highly uniform to perform well.

Each breeder should measure improvements in a new variety against time. In doing so, time should be treated as a valuable commodity and weighted heavily.

Breeding for Disease Resistance - There is a continuing need to evaluate alternative procedures of breeding for different characters. At the present time, there is much being said about the need to adopt alternative ways of breeding for disease resistance. We are being bombarded with the notion that the old method of disease breeding is no longer acceptable, i.e. major genes are easily overcome by the pathogen and hence don't offer good protection. Since my experience is not consistent with this view, I challenge it. In Minnesota, the sources of resistance that were identified 10-30 years ago are still providing protection today. The outstanding example is the T gene which has conditioned a high level of resistance to stem rust in several different varieties for nearly 30 years.

Some of you may be involved in a disease situation that requires an alternative approach to the use of major genes. It is my judgement, however, that most barley breeders will be ahead if they do disease breeding in the old way. We know how to handle so-called major genes, often in a very efficient way. A second reason for advocating the old way is that the alternatives are not very attractive. Multiline breeding (involving numerous backcrosses) is expensive and it appears to be a suitable procedure in relatively few situations. Breeding for generalized resistance looks promising, but it is in its infancy. We need more information before adopting it, at least in most circumstances.

Selecting Parental Varieties - One of the most important decisions in a breeding program is selection of parental varieties. When a cross is made, it sets in motion a sequence of events that are expensive in resources and time. Furthermore, the parents set a genetic limit on the progress that can be made from selection.

In thinking about selection of parents, I find it useful to consider two types of crosses or types of breeding: combination breeding and transgressive breeding. In combination breeding the objective is to incorporate two or more characters from two or more varieties into a single variety, whereas, in transgressive breeding the objective is to enhance a single character by accumulating genes for the character from different parents. In combination breeding, parents are selected that have the desired phenotype for the characters that are of interest. The goal is to combine the characters (for example) disease resistance and lodging resistance in the newly derived variety while retaining the level of performance for each character that was present in the different parents.

In transgressive breeding, yield is a common objective and the aspiration is to obtain higher yield than occurs in existing varieties. Two criteria are especially important when doing transgressive breeding for yield. The most important one, in my view, is the yield performance of the potential parent. Two arguments can be made in defense of this assertion. I believe that the accumulated experience of plant breeders indicates that good performing lines or varieties make the best parents; they are most likely to give high yielding progeny. The second argument is that genetic variance estimates indicate that gene action for yield is predominantly additive. If the latter is true, then parental performance should provide a good index of the performance of the progeny.

The second criterion is the phenotype of the potential parents for yield related traits. The argument is that traits such as tillering capacity, kernel number, lodging resistance and maturity influence yield, and thus a breeder should concentrate on those parents that have favorable expressions of such traits. Other considerations such as breeding record, when it exists, and the diversity of germplasm may be useful. In any event, selection of parents should not be done casually, whether doing combination or transgressive breeding.

Summary

The purpose of the report was to suggest ways of obtaining greater progress in barley breeding programs. The choice of what research to do and the characters to emphasize are considered, as are choices relating to breeding methods and ways of obtaining good progress with these methods.

It is emphasized that greater progress is possible if breeders concentrate more on applied breeding and less on related research. The importance of the choice of characters to handle in the breeding program with a goal of keeping the number small and emphasis on those deemed most important is emphasized. Breeding procedures are discussed and suggestions made for shortening the time required for variety development. These include obtaining two or three generations per year, modifying certain steps, and eliminating others. Ways of making disease breeding more effective and criteria for use in selecting parent varieties are discussed.

BREEDING WINTER BARLEY AND THE EXPLOITATION OF SPRING X WINTER CROSSES

G. Jenkins*

Between the extremes represented by a single plant pedigree system on the one hand and bulk breeding methods on the other there are probably as many variants in selection procedure as there are barley breeders. Because the crop is normally self-pollinated most breeders use some form of pedigree selection, commonly an F_2 progeny system. The techniques of pedigree selection are well known and will not be discudded here, consideration being given instead to other approaches, especially those which may be used to accelerate a breeding programme.

Alternatives to Pedigree Selection

Hybrid barley as a commercial possibility, in Europe at least, is still in the experimental stage and the developmental work so far has been largely confined to spring barley. However, the numerous genes for malesterility which have been identified and which at present provide the basis for work on hybrid barley have enlarged the scope and flexibility of composite cross populations in which varying degrees of heterozygosity are maintained. The use of composite cross populations has been the subject of a recent but unpublished review (Wesenberg, 1974). In North America the use of composite hybrid mixtures received an early stimulus from the work of Harlan and Martini (1929), the first composites being simple mixtures of single crosses. Their composite cross III (CI 5530) was a winter barley composite originating in this way. Composite cross XIV was the first to exploit the discovery of a nuclear male sterile by Suneson in 1940 and was produced by him at Davis, California in 1944. All composite cross populations subsequently designated have used nuclear male steriles in their production. In his review Wesenberg reports an unregistered winter composite produced by Wiebe in which significant gains over the parents in winter hardiness were achieved. Up to 1956 some 17 varieties, 12 of them winter types, had been released from composite crosses in the US and Canada. By 1974 only one variety grown in the 10 largest barley-producing states of the US could be positively identified as originating from a composite cross population but several others derived

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part of their parentage in this way. Outside this area the variety Kearney, one of the hardiest entries in the world collection was selected from a composite cross population. Of recent releases, CC XXVI and part of CC XXX have been developed as winter barley populations. A survey conducted by D.M. Wesenberg and J.C. Craddock in 1974 elicited numerous replies from barley breeders in North America, Europe, Australia, Japan, Mexico and Turkey. About 75% of the respondents indicated that composite cross breeding played some part in their programmes but more than 90% of these devoted less than one quarter of their effort to such projects. Improved winter hardiness figured prominently in the stated objectives of these composite crosses.

The present trend in composite cross breeding is to select for improvements in quantitative characters in repeated cycles, using techniques appropriate to each particular character, a procedure which has been described as "male sterile facilitated recurrent selection". This application of male sterility theoretically permits recombination which would not otherwise be obtainable without an excessive amount of hand pollination. Too much recombination however could be disadvantageous if it resulted in the breakup of desirable linkages. The breeder is seldom in the position of being sufficiently well informed about the genetic architecture of his material to decide on the balance of these possibilities. Composite cross populations are long term projects which are probably most useful where advances are sought on a broad front and where the selection pressure applied is all-important.

The choice of handling procedure is to a large extent determined by the situation in which a breeder works. At the Plant Breeding Institute we have traditionally used a fairly orthodox pedigree selection programme. We think that this is still the best way to produce varieties which are likely to meet the stringent and often restrictive standards of distinctness and uniformity required by legislation in Britain and certain other European countries. Where rather more variability within a variety is tolerated a less intensive selection system can be applied and material can be released in an earlier generation. Our winter barley programme has the strictly defined objectives of retaining the malting quality of the present dominant variety while improving its agronomic characters. The end product and the procedures to be adopted to achieve it are therefore fairly clear cut but one of the main obstacles is the length of time it takes to produce lines to submit to the National List trials system. In our pedigree system this normally takes at least six or seven years followed by three years obligatory official trials before a new variety is multiplied on any scale for subsequen commercial release. In the highly competetive situation of European barley breeding we are much concerned with ways of reducing the time it takes to produce varieties.

The Use of Dihaploids

The longer life cycle and typical vernalisation requirement of winter barley normally precludes the acceleration of a breeding programme which can be achieved with a spring crop by using alternating nurseries in Northern and Southern hemispheres. For this reason and because such schemes are expensive to operate the production of dihaploids as a means of achieving instant homozygosity might be considered to have greater application to the breeding of winter rather than spring barley. The production of haploids by pollen or another culture has not been successful, at least on the scale which would be required in breeding programmes. Since the report by Kasha and Kao (1970) that haploids of Hordeum vulgare could result from pollination by H. bulbosum, this technique has advanced to a stage where its application in breeding programmes is now a reality (Kasha and Reinbergs, 1976; Jensen, 1976).

A scheme outlining how the production of dihaploids could be applied to a winter barley breeding programme is outlined in Fig. 1. From this it is evident that homozygous lines could be entered in preliminary yield trials within three years of making the initial cross between the chosen H. vulgare parents. The disadvantages of this technique are equally apparent, the principle on being that apart from the effects of linkage the amount of genetic recombination is fixed at the time of pollination by H. bulbosum i.e. by the number of haploid grains produced. Since these are the result of individual hand-pollinations, there are clearly limits to the extent to which the technique can be used in a particular programme. It has been calculated for example that even with as few as six independently segregating loci the expected frequency of gametes capable of producing a postulated desirable genotype is only 0.0156, compared with 0.178 for zygotes from the F_1 plants (Walsh, 1974). The realization of genetic potential of an F_2 is obviously dependent on the ability of the breeder to select superior genotypes and if severe constraints are placed on the size of the F_2 population handled, the haploid method becomes relatively more attractive particularly where the character selected has a low heritability. The haploid technique however, requires a high level of expertise and the availability of special facilties, particularly for the critical phase of embryo culture of the haploids. Furthermore, the extreme compression of the pre-trial phase has attendant disadvantages in reducing the time available for discarding unwanted genotypes. Consequently it is particularly desirable to apply regorous selection criteria for such characters as disease resistance, frost resistance or grain quality during the multiplication phase (year 2, Fig. 1).

The use of haploids in a winter programme is probably best restricted to special situations with limited and clearly defined objectives, since the number of haploids which could be generated would be unlikely to sustain a major programme in its entirety.

Single Seed Descent

An alternative procedure for producing homozygous material more rapidly is that of single seed descent (SSD) in which densely crowded populations are grown with low nutrient supply, resulting in a shortening of the life cycle to 12 weeks in the case of spring barley. This method requires much simpler technology than that involved in haploid production but its use has largely been confined to spring cerals. Snape and Riggs (1975) reviewed some of the recent literature and considered theoretically some of the genetical consequences of using SSD. They concluded that although genetic advance may not be maximised under these conditions transgressive segregation can be fixed and thus improvements made over the parents with advantages of saving in time and effort.

The longer life-cycle of winter barley naturally makes it less suitable for the SSD technique. Nevertheless some attempt to summarise its possible applications to a winter programme has been made (Fig. 2). There is a choice between gaining one year over the normal pedigree selection cycle or entering lines into yield trial at the same time but in the F_7 instead of the F_5 generation. It would clearly be of advantage if some selection pressure could be applied during the SSD generations. We have experimented with our standard technique for assessing frost resistance in winter barley (Jenkins and Roffey, 1974) and found that this can be used with detached leaves. Selection for this important character could therefore be made in winter barley grown by the SSD method although relating frost assessments made on detached leaves to the unfrozen seedlings would be very tedious on a large scale.

With SSD populations of reasonable size, e.g. 1500 plants the computer simulation study by Snape and Riggs suggested that genetic drift would not be serious. Clearly, however, this would be aggravated if uncontrolled shifts occur in the population as a result of plant loss. A recent paper reported plant losses approaching 20% with spring barley (Riggs and Hayter 1976) and the results indicated that these were not randomly distributed. It was therefore of some interest to assess the practical problems which can arise from the use of SSD in winter barley where a vernalisation requirement is an added avariable.

A detailed SSD experiment was conducted in 1975 with the assistance of Rose-Marie Spence (nee Grace). This involved fully randomising individual seeds of 12 winter barley varieties of contrasting phenotypes on pre-marked grids in boxes measuring 35 x 25 x 5 cm to give a planting density of 2840 seeds/m^2. Three vernalisation treatments were applied of four, six or eight weeks duration and two temperature treatments during vernalisation: 4°C constant and 8°C (day) alternating with 4°C (night). During vernalisation the photoperiod was maintained in a growth room at 10 h with a light intensity of 61 W/m^2. There were two replications

(boxes) of each of the six treatments. After vernalisation, the boxes were moved to a warm glasshouse with a 20 h photoperiod maintained by high pressure sodium lamps and the plants fed weekly with a balanced culture solution. Observations were recorded on individual plants of the number of days from sowing to heading, height, grain number, grain weight, and on the numbers of plants dying after germination, the number surviving but failing to head and the number which headed but which were sterile. For all these characters there were significant effects for varieties and for the duration of vernalisation treatment but no significant effect of temperature treatment during vernalisation. There was a significant interaction between varieties and duration of vernalisation with respect to number of days to heading and also the proportion of plants failing to head. In general, increasing the duration of vernalisation reduced time to heading, grain number per plant and mean grain weight (Table 1). However the total proportion of unproductive plants was lowest with the middle vernalisation treatment of six weeks. Main effects for varieties over all treatments are summarised in Table 2. In SSD work the essential requirement is that a high proportion of the initial population survives to produce one viable seed per plant. The interplanting of contrasting phenotypes in this experiment could be assumed to simulate conditions in a segregating population derived from contrasting parents. It is immediately clear from these tables that there were marked genotype x environment interactions resulting in large differences in genotypic survival as reflected in the proportions of dead, vegetative and sterile plants. In general, varieties with the highest proportion of unproductive plants were those with the lowest mean height. The most successful varieties tended to be tall, later maturing types but short late, varieties such as FDE 252 or Katy were at a particular disadvantage. The two alternative (facultative) barleys Ankara Tokak and 13031 produced contrasting results. Significant interactions between varieties and vernalisation treatment for the proportion of plants failing to head are summarised in Table 3, which gives some indication of the complexity of response. Further complications were evident in a significant interaction between temperature treatment and duration of vernalisation for various characters measured but, in general, alternaing vernalisation temperature produced a more favourable response. Clearly it would be extremely difficult to specify a standard SSD regime for growing winter barley populations which might be segregating for vernalisation requirement, maturity, height and head type.

It will be apparent from the preceeding discussion that most of the procedural problems of winter barley breeding arise from the vernalisation requirement, and consequently longer life-cycle, which reduces flexibility in handling. The principal agronomic requirement of a winter cereal is that it survives the winter to provide some advantage, usually in yield, compared with spring sowing. If winter survival is not necessarily dependent on the possession of characters usually associated with typical

winter types, i.e. strong vernalisation requirement and marked photoperiod response then it should be possible to select genotypes which could be handled as spring varieties but having the capacity to overwinter. Part of our programme at the Plant Breeding Institute in recent years has been concerned with the development of this kind of material (Jenkins, Kirby and Roffey, 1976). Using appropriate selection procedures it has been possible to derive lines which combine good frost resistance with little vernalisation requirement and relative insensitivity to short days. Since it was necessary to use exotic germ plasm to produce the initial cross the material derived from this programme so far is unadapted and not suitable for immediate agricultural exploitation in England. The compression of the time scale for apical development in these lines also appears to have reduced potential yielding ability. However, we are now in the process of backcrossing to more adapted varieties, with the aim of reselecting the same pattern of development responses in higher yielding lines. Material of this kind may have some application in those areas of the Middle East where barley is winter-sown at high elevations subject to frost but where early maturity is nevertheless required. From our point of view the availability of such material would remove many of the present constraints upon the acceleration of winter barley breeding.

Spring X Winter Crosses

On a world basis, barley is essentially a spring sown crop. In the USDA collection at Beltsville, from a total of 17,400 barley entries only 2,350 are classified as winter types and a mere 50 as alternative (facultative) forms, the remainder consisting of spring varieties (J.C. Craddock, 1977). It has been argued that wheat breeding would benefit from the genetic recombination resulting from more extensive crossing of spring and winter varieties (Anon. 1972). The literature on spring x winter crosses in barley, for general breeding purposes as opposed to specific genetic investigation, is sparse. Where such work has been reported however, it almost invariably has the objective of improving the winter crop by gene transference from the larger spring variety pool. Most commonly, the genes transferred determine improved grain quality or shorter straw. Indeed the development of the winter barley crop in England has been almost entirely due to the use of spring varieties as donors of malting quality to more primitive winter-hardy forms of poor quality (Bell, 1944). That winter varieties are seldom used as parents for the improvement of spring barley is perhaps not surprising since a crop which is grown from the Arctic Circle to the drier tropics may be deemed not to suffer from a conspicuous lack of variability. Since many of the desirable genes for such characters as short straw and superior grain quality for malt or feed are concentrated in spring barleys the question arises as to whether there are benefits to be derived from the use of winter barleys in improving the spring crop. One possible area of exploitation is that of disease resistance. Some data from the Plant

Breeding Institute barley collections, provided by my colleague G.E. Porter, are presented in Table 4 in which resistant varieties are defined as those having an average field disease score of 3 or less on a 1-9 scale. The relatively greater number of winter barleys having resistance to certain diseases, particularly leaf blotch (Rhynchosporium secalis) and yellow rust (Puccinia striiformis) suggests that the winter barley collection could usefully be exploited although most of these resistant sources have not been genetically analysed.

However, in the agricultural situation of the United Kingdom a merger of resistance sources between winter and spring crops must be viewed with caution. Unlike the situation in Belgium or Northern France where in recent years the cultivation of barley has swung over almost entirely to winter sowing, winter barley in Britain still accounts for only 10 to 12% of the total barley area. Following mild winters there is a considerable risk of disease carrying over from the winter to the economically more important spring crop. This has been demonstrated most commonly for powdery mildew (Erysiphe graminis) (Yarham and Pye, 1969). There is also strong circumstantial evidence that yellow rust, not considered a serious disease of barley in the UK until the last few years, has increased in importance following the introduction of the susceptible winter variety Astrix. In other countries where there is no such overlap between winter and spring crops of unequal economic significance, the transfer of disease resistance genes from winter barley need not suffer the same restriction. Indeed for other agronomic characters there may be considerable advantages to be derived from spring x winter hybrids. In our own programme we have selected some transgressively early maturing short-strawed spring barleys from such a cross. Winter barley with its limited gene pool will certainly require further introgression of genes from spring barleys for its continued improvement in the years ahead.

REFERENCES

Anon. (1972) Annual Report, Centro Internactional de Mejoramiento de Maiz y Trigo. pp 25-26.

Bell, G.D.H. (1944) The breeding of two-row winter barley. J. Agric. Sci., Camb., 34, 223-8.

Craddock, J.C. (1977) Personal communication.

Harlan, H.V. and Martini, May L. (1929) A composite hybrid mixture, Agron. J. 21, 487-490

Jenkins, G. and Roffey, A.P. (1974) A method for estimating the cold hardness of cereals by measuring electrical conductance after freezing. J. agric. Sci., Camb., 83, 87-92

Jenkins, G., Kirby, E.J.M. and Roffey, A.P. (1976) Selection for developmental responses in winter barley. J. agric. Sci., Camb., 87, 591-598

Jensen, C.J. (1976) Barley monoploids and doubled monoploids: techniques and experience. Barley Genetics III (Ed. H. Gaul), 316-345.

Kasha, K.J. and Kao, K.N. (1970) High frequency haploid production in barley Genetics III, 307-315.

Riggs, T.J. and Hayter, A.M. (1976) Practical aspects of the single seed descent method in barley breeding. Barley Genetics III, 708-717.

Snape, J.W. and Riggs, T.J. (1975) Genetical consequences of single seed descent in the breeding of self-pollinating crops. Heredity 35, 211-219.

Stephanov, T. and Gorastev Ch. (1976) Using of induced mutagenesis and intervarietal hybridisation in winter two-rowed barley breeding. Barley Genetics III (Ed. H. Gaul), 197-202.

Walsh, E.J. (1974) Efficiency of the haploid method of breeding autogamous diploid species: a computer simulation study. Proc. 1st Internat. Symp. Haploids in Higher Plants (Ed. K.J. Kasha) Univ. Guelph, 195-209

Wesenberg, D.M. (1974) Personal communication.

Yarham, D.J. and Pye, D. (1969) Winter barley as a source of mildew for spring barley crops. Proc. 5th Br. Insectic. Fungic. Conf. 25-33.

Fig. 1 Use of haploids in winter barley breeding

Year		
1	January/February	Sow parents. Vernalise.
	May/June	Make cross.
	July/August	Sow F_1. Vernalise.
	December	Cross F_1 x *Hordeum bulbosum*
2	January-July	Embryo culture. Vernalise. Colchicine.
	August	Harvest di-haploid seed.
	September	Vernalise and multiply in glasshouse.
3	January/February	Sow progenies in field.
	July/August	Harvest.
	October	Sow YIELD TRIALS.
4	July/August	Harvest YIELD TRIALS.

Figure 2. Winter Barley Breeding

Possible use of single seed descent(SSD)

(Assume F_2 seed is available in September of Year 2)

Year		Normal procedure	With 1 generation SSD	1 generation SSD
2	Sept.		Sow SSD F_2	Sow SSD F_2
	Oct.	Sow F_2 (field)		
3	Jan.		Harvest F_2	Harvest F_2
	Feb.		Sow F_3 (field)	Sow SSD F_3
	June			Harvest F_3
	July/Aug.	Select F_2 plants	Select F_3 plants	Sow SSD F_4
	Oct.	Sow F_3(field)	Sow F_4(field)	
	Dec.			Harvest SSD F_4
4	Jan.			Sow F_2(field)
	July/Aug.	Select F_3 lines	Select F_4 lines	Select F_5 plants
	Oct.	Sow F_4(field)	Sow F_5 lines + YIELD TRIAL	Sow F_6(field)
5	July/Aug.	Select F_4 lines	(Continue trials)	Select F_6 lines
	Oct.	Sow F_5 lines + YIELD TRIAL		Sow F_7 lines + YIELD TRIAL

Table 1. Winter barley - single seed descent: main effect of vernalisation treatment

(Mean values)

Duration of vernalisation (weeks)	Time to head (days)	Plant height (cm)	Grain number per plant	Grain weight (mg)	Plants failing to head (%)	Dead Plants (%)	Sterile plants (%)
4	65.7	30.6	2.5	3.1	17.6	7.6	29.2
6	46.9	29.4	2.3	3.2	8.3	5.7	26.8
8	40.2	25.3	1.9	2.5	27.4	18.6	40.3
S.E ±	0.60	0.56	0.09	0.13	2.80	2.07	2.57

Table 2. Winter barley grown in single seed descent conditions - variety effects

(Mean values)

Variety	Vernalisation requirement*	Plant height (cm)	Time to head(days)	Plants failing to head(%)	Plants dead(%)	Plants sterile(%)
Weibulls 1001	S	35.7	62.7	19.3	20.8	9.0
Graupenkorn	S	36.7	48.2	5.4	11.1	4.9
Katy	S	26.0	70.3	39.7	15.2	35.7
Astrix	S	18.9	45.1	14.4	8.3	57.1
FDE 252	S	17.1	58.7	26.0	12.5	86.0
Maris Trojan	S	38.2	65.9	25.8	1.4	25.8
Pioneer	M	34.5	58.3	15.2	7.6	15.1
Maris Otter	M	28.6	49.9	16.8	10.4	16.4
Kearney	M	26.9	35.9	5.4	3.5	24.3
Maris Puma	W	26.8	41.7	18.1	9.0	16.8
Ankara Tokak	O	28.3	39.7	8.9	20.1	17.9
13031	O	23.6	34.9	18.4	7.6	76.4
S.E ±		1.1	1.2	5.6	4.0	5.1

* S = strong, M = moderate, W = weak, O = none (alternative)

Table 3. Winter barley - single seed descent
Plants failing to head: variety x vernalisation effects

(Per cent)

Variety	Vernalisation duration (weeks) 4	6	8
Weibulls 1001	32.4	5.8	19.8
Graupenkorn	9.0	2.1	5.0
Katy	39.3	31.0	48.9
Astrix	0	13.2	29.9
FDE 252	31.8	21.2	24.8
Maris Trojan	56.1	6.2	15.0
Pioneer	10.4	2.3	32.8
Maris Otter	10.0	4.5	35.9
Kearney	2.3	2.1	11.8
Maris Puma	17.8	8.3	28.1
Ankara Tokak	2.5	2.5	21.6
13031	0	0	55.2

S.E = ± 9.76

Table 4. PBI Barley Collection - Disease Reactions

Type of variety	Powdery mildew (*Erysiphe graminis*)		Brown rust (*Puccinia hordei*)		Yellow rust (*P. striiformis*)		Leaf blotch (*Rhynchosporium secalis*)	
	Number tested	Number resistant (%)	Number tested	Number resistant (%)	Number tested	Number resistant (%)	Number tested	Number resistant (%)
Winter	254	53.5	240	47.9	244	73.8	239	73.2
Alternative	173	49.1	73	46.6	159	70.4	180	56.7
Spring	1128	23.1	973	56.3	721	39.4	935	49.4

MALE STERILE FACILITATED RECURRENT SELECTION -ADVANTAGES AND DISADVANTAGES-

Robert F. Eslick*

Plant breeding within self-pollinated crops may be divided into two general phases: 1. determination of the parental material from which selection of new cultivars will be made or "resource material development" and, 2. Actual selection, purification and testing of lines that will ultimately yield the desired cultivar, "exploitation". This discussion will be concerned primarily with "resource material development".

We have previously discussed a more or less typical pedigree breeding program as represented by barley breeding for the mid-western United States, Eslick and Hockett (1974). One is led to the conclusion that this program, during the past 75 years, represents a slowed recurrent selection program necessitated by the requirement of the retention of a complex of 6-row malting quality factors present in the old introeuced Manchurian varieties. If one is to speed up such a recurrent selection program through pedigree breeding then it becomes a numbers game, many crosses and large numbers of progeny.

As I understand the basic CIMMYT (1976) wheat breeding program, it probably represents the most accelerated recurrent selection program with a self-pollinated crop present in the world today. It is typified by large numbers of crosses (3-4000 per year), large acreage of progenies, and selection of parents from any generation, F_1-F_{10}, followed with pedigree breeding and evaluations of one type or another. One could predict that as frequency of desirable characteristics are increased in a germplasm pool of this type that genetic diversity will decrease and introduction of additional germplasm will become necessary and more difficult if further progress is to be made.

If one recognizes the two foregoing programs as examples of recurrent selection, and recognizing they have been successful approaches in many ways, then one should consider deliberately devising the best possible recurrent selection program for use with naturally self-pollinated crops such as wheat and barley. Forage breeders rely

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heavily on recurrent selection in one form or another and many of the principles for recurrent selection have been established with maize. It should be mentioned that principles established with corn and its accumulation of deleterious genes, evident upon selfing, may not be directly transferable to barley that is naturally selfed and represents an accumulation of desirable genes as represented in many of our cultivars.

I would like to contrast two systems of barley breeding that seem to have not been sufficiently distinguished between or adequately evaluated. They are most generally lumped under the general term "composite cross breeding". It would be appropriate to first briefly review the history of composite crosses (CC's) I through XIII.

Composite crosses or composite hybrid mixtures of one or more crosses were probably first used in Canada and Sweden in the early 1900's. Harlan and Martini (1929) were among the first to publish on composite crosses. The first of these, CC I, CC II, CC III, were bulks of a number of single crosses. The second innovation on thus system waa the introduction of a series of "bridge crosses" which consisted of inter-crossing F_1's and then intercrossing these F_1's until, theoretically, a given plant might possess germplasm from all varieties entering into the composite cross, Harlan, et al. (1940). Establishment of this type of composite cross without male sterile in the population was very time consuming, required several generations and limited the number of recombinants. These procedures were followed through CC XIII. From this material some 19 cultivars were released in the United States. They included Cascade,, Compana, Davidson, Dayton, Eklis, Frontier, Grande, Harbine, Harlan, Kearney, Kenate, Kenbar Mo. B-475, Nassau, Rogers, Rojo, Santiani, Spray, and Texan. These varieties occur in the parentage of at least nine other varieties.

Suneson described the first genetic male sterile, msg1, in 1940. Some 28 separate loci for male sterile have subsequently been identified and many of these assigned to chromosomes, Hockett et al (1968). All composite crosses assigned numbers XX XIV through CC XXXIII by the U.S. Department of Agriculture have included one or more of the male sterile genes.

Suneson (1956) described his use of composite crosses and implied that natural selection should be relied upon to produce significant gains. Suneson and Wiebe (1962) described the formation of XX XXI.

Male Sterile plants from XX XIV, CC XV and Coast, Manchuria, Trebi, and Hannchen cultivars were recipients of pollen from some 6200 accessions of spring barleys in the world collection to form XX XXI. The emphasis on utilization of this composite cross was to permit natural selection to accomplish the desired end. At the first meeting of the International Barley Genetics Symposium, Suneson (1963) summarized his work and attitudes concerning composite cross breeding. He suggested that 90% of a research effort might well go to resource material development and 10% to exploitation (variety development) rather than 90% to exploitation (including yield testing) and 10% to the development of basic breeding materials. Perhaps there is a happy medium.

How has reliance on natural selection worked in practice ? My assumption (and Suneson's) would be that yields of the composite cross would increase over time. We have grown composite crosses for as many as 30 consecutive generations on dryland at Moccasin, Montana. Yield increases have been early non-existant. Perhaps yield increases can be realized by natural selection only in some environments or when natural selection is effective for certain traits.

With the advent of populations that contain male sterile it is unfortunate that Dr. Suneson did not emphasize the role these populations could play as contrasted to the old composite crosses (CC) in a recurrent selection program. A few years ago it was decided that we really should refer to these as "male sterile facilitated recurrent selection populations" (RSP's) and that one should not necessarily rely on natural selection to shift the population in the desired direction.

The remainder of this discussion will consist of contrasting the two types of populations. The same list of criteria, with additions, may be used to contrast other breeding systems.

In both systems of breeding large populations may be grown with ease and a minimum of record keeping.

The presence of male steriles in the population, RSP, permits large numbers of crosses when the material is grown so as to enhance cross pollination. Several hundred pounds of naturally outcrossed F_1 seed have been harvested from a single population. I am aware of one program that produces 20-30 lbs. of hand-crossed seed each year.

Initial gene combinations were quite limited in the early composite crosses, CC's, while among the currently available RSP's CC XXI potentially had 6200+ parents, made possible by the presence of male sterility. Subsequent forced outcrossing will accomplish much more successfully the bridge crossing of F_1's used to establish much more successfully the bridge crossing of F_1's used to establish the earlier composite crosses.

Recurrent selection populations, such as CC XXX, will have a great amount of genetic diversity present. It will have gene combinations that have never occurred before and would probably never occurred before and would probably never occur if hand pollination of single crosses were relied upon. It should be looked upon as a source of the unusual. The frequency of good agronomic types will be low.

Continued crossing will tend to break up long established linkage blocks. Who is to say that those we have today are the most desirable ? With a diploid, such as barley, isn't this one of the accomplishments of most breeding programs ?

One method of controlling genetic diversity is to limit the number or kinds of parents entered into the population. With the early composite crosses (CC's) one was limited in the number of parents that could be included. In the RSP's as few or as many parents (e.g. 12,000 as in CC XXX) as desired may be included in the population. After growing and evaluating CC XXI in England, Whitehouse (1967) observed that "Plant breeders might do better to use their knowledge to construct populations adapted to local conditions and to apply their skills in selection rather than leaving nature to do it for them". It may be that there were many desirable plant types in CC XXI that could have added needed genetic diversity to a germplasm pool of the current English cultivars. As an example of restricted parents we have established two RSP's, one 2-row and one 6-row, each with 15 cultivars. The cultivars for these were selected primarily on the basis of wide adaptation and success as cultivars somewhere in the world, primarily on dryland.

A second obvious method of controlling genetic diversity is to shift the population mean by rogueing undesirable types or selecting only desired types. Ramage has used selection very successfully in the development of short strawed populations

(non-erectoides) by selecting for this type of plant within CC XXX and other RSP's. We have used rogueing to increase the frequency of scald resistance, and other diseases, within CC XXX. This may be accomplished for any trait that may be evaluated on a single plant basis.

A third method of controlling the population mean would consist of topcrossing or backcrossing into the population, RSP, a parent or parents that had a high frequency for the gene or genes that would effect the desired shift. Grafius (1965) has emphasized the importance of having the population mean for as many traits as possible as near that of a postulated ideal cultivar as possible before starting selection. For those interested in mathematical approaches, his methods could be used to select parents for recurrent selection populations.

New germplasm may be introduced into a population, RSP, at anytime. Methods of doing this can be devised that do not require "starting over".

If we were to develop a population that contained all of the genes for resistance to a particular disease, e.g. scald resistance, and were to practice alternating sib-crossing and selecting for resistance, individual plants would begin pyramiding alleles for resistance, i.e. have several resistant genes present. We have distributed a population with this as the objective. This may well be accompanied by selection for agronomic type. Such a population should provide a better source of scald resistant genes than is currently available as well as reducing genetic vulnerability. New linkage groups may be established.

Another proposed method for reducing genetic vulnerability suggests that minor genes be accumulated in individual plants to provide the resistance. RSP's provide the most feasable approach to developing this type of resistance as large numbers of recombinations are necessary and possible. The method would call for starting with a homogeneous susceptible population and searching for acceptable levels of resistance among the recombinants.

There are other reasons for accumulating minor genes or detecting specific rare genes that the method lends itself to. One of these would concern overcoming the association of high lysine and shrunken seed. Assuming minor genes for plumpness or a specific suppressor gene of shrunken endosperm exists in the world barley collection, then, with a population homozygous for the high lysine

and containing the world germplasm a recurrent selection program for large seed (sieving) could be followed. Perhaps plump high lysine types may be isolated.

Continuous selection for desirable agronomic types within F_1 and F_2 populations should result in a population of plants that have fewer undesirable epistatic effects when used in crosses, particularly among themselves. The frequency of desirable epistatic effects could likewise be increased. How often do we choose two good inbred parents, make the cross, and eventually discard the progeny of the entire cross ?

One might debate the desirability of the next point which should be obvious from the fore-going. Improvement of RSP's places a premium on rapid accurate methods of evaluating individual plants. Plant breeders have been negligent in developing techniques and expertise in this area. Plant breeders who do not have complete familiarity with their crop (or develop it), the association of traits desirable and undesirable, who are not stimulated by observation of diversity, or who are not keen observers should probably continue with plant row evaluation. Plant rows can be used in connection with RSP breeding but will tend to reduce genetic diversity in the population by genetic drift, i.e. too small a population continued.

When working with RSP's isolation from other barley may be required. This may somewhat depend on the objectives, and on the generation (whether selfed, sibbed, etc.) being grown.

In a forced outcrossing population most plants selected will be heterozygous for a number of traits and two-thirds of the fertile lines selected may be expected to segregate male sterile. If RSP's are grown under conditions that do not favor cross pollination and harvested in bulk or if the male steriles are rogued, the male sterile will be eliminated rapidly and a greater degree of homozygosity will be present in the remaining plants before the potential of a portion of a population is exploited.

The following table presentd those characteristics discussed in summary form.

Summary table of characteristics for evaluating composite crosses and male sterile facilitated recurrent selection populations.

Composite Cross Population, CC's	Characteristics Compared**	Recurrent selection populations, RSP's
	Development of Resource Material	
*	Population size grown	*
	Many parents may be used	*
	Maximum amount gene recombination	*
	Selected level of genetic diversity	*
	Serve as a source of unusual genotypes	*
	Established linkage blocks may be broken	*
	Population mean may be shifted anytime	*
	Desirable germplasm easily added	*
	Genes for a trait may be pyramided	*
	May accumulate minor genes for a trait	*
	Epistatic effects may be altered	*
	Premium on individual plant evaluation	*
*	Record keeping reduced	*
*	Isolation may be required	
	Exploitation of Resource Material	
*	Elimination of segregation for male sterility	
*	Attainment of acceptable degree of homozygosity	

* Indicates population type favored in CC's or RSP's

** See test for additional detail.

Agree or disagree, one wonders why we have not heard more of the RSP method of plant breeding. Probably because of the relative few workers in this area and the fact it is primarily concerned with development of resource material, initially, and not exploitation. It could be added that only recently has the concept of applying heavy selection pressures to the populations and not depending on natural selection been acted upon. The most active programs are those of New York, Montana, and Arizona in the United States, Saskatchewan in Canada, Sweden, and a private breeding company in England. Other programs are known to exist in North Dakota, South Dakota, Wisconsin, California, Idaho, Kansas, Wyoming, and Michigan in the United States, Ontario in Canada, Korea, and possibly Egypt.

I have attempted to cover some aspects of recurrent selection population breeding as it applies to barley. Many items need yet to be discussed and debated; among them methods of management to attain certain goals, selection criteria, special genetic applications, etc. If this discussion in any way results in any breeder giving more attention and time to the evaluation and development of his resource material before starting exploitation it will have been time well spent.

References

Anon. 1976. CIMMYT Review 1976 pp.1.

Eslick, R.F. and E.A. Hockett. 1974. Genetic engineering as a key to water use efficiency. Agr.Meter.14:13-23.

Grafius, J.E. 1965. A geometry of plant breeding. Mich.Agr.Exp. Sta.Res.Bull. 7:1-59.

Harlan, H.V. and M.L.Martini. 1929. A composite hybrid mixture. Jour.Amer.Soc.Agron.21:487-490.

Harlan, H.V., M.L.Martini and H.A.Stevens. 1940. A study of methods of barley breeding, USDA Tech.Bull. 720.

Hockett, E.A., R.F.Eslick, D.A.Reid, and G.A. Wiebe. 1968. Genetic male sterility in barley. II Availabl e spring and winter stocks. Crop Sci. 8: 754-755.

Suneson, C.A., 1940. A male sterile character in barley. Jour. Hered. 31: 213-214.

Suneson, C.A. 1956. An evolutionary plant breeding method. Agron. Jour. 48: 188-191.

Suneson, C.A. 1963. Breeding techniques - Composite crosses and hybrid barley. Barley Genetics I, centre for Agricultural Publications and Documentation, Wageningen, Netherlands. pp. 303-309.

Suneson, C.A. and G.A. Wiebe. 1962. A "Paul Bunyan" plant breeding enterprise with barley. Crop Science 2:347-348.

Whitehouse, R.N.H. 1966. Experience with CC XXI in England, Barley Newsletter 10: 115-116.

MALE STERILE FACILITATED RECURRENT SELECTION AND HAPPY HOMES

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The purpose of plant breeding is to increase or stabilize yields of desirable plant parts or products. Yield and traits that tend to stabilize yield are characters that are under genetic control. A fundamental tenet of genetics is that every characteristic of every living organism is a product of an interaction of a specific genetic constitution with a specific environment. In practicing plant breeding, one should keep in mind that there are no "yield genes" per se. The phenotype of a plant, including iys yield, is the result of all of the genes of the plant interacting with each other and with the environment. A successful cultivar is one that has a genotype that is balanced to accommodate the particular genetic characters of that cultivar, i.e. a successful cultivar has a genotype that is balanced to accommodate the particular plant height, maturity, leaf width, chlorophyl content, etc. of that cultivar.

There exists an optimum balance between the action of a particular gene and its background genotype. Each character or combination of characters has a background genotype that is most favorable for the expression of that character or combination of characters. This "most favorable background genotype" we are calling a "happy home". Our premise is that there is a "happiest" home for every character or combination of characters and that the purpose of plant breeding is to select the happiest home for the particular combination of characters that a cultivar must possess. Plant breeders have been using this concept for a long time. We propose to re-examine it in relation to recent work done with mutation breeding, isogenic analysis and breeding methodology.

We became acutely aware of the balance between a particular gene and its background genotype when we compared short-straw mutants selected in heterozygous and homozygous material. Seed that were homozygous for the male sterile allele, msg2, were obtained by crossing tertiary trisomics balanced for msg2 onto male sterile diploids in the BTT line 63-j-18-17 (this line is the female parent of the commercial hybrid 'Hembar'). The crossed seed, which would produce

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only male sterile plants, were treated with the chemical mutagen, diethyl sulfate. The treated seed were planted in the female rows of a standard crossing block. Untreated seed of the cultivar 'Arivat' were planted in the male rows (Arivat is the male parent of Hembar). The crossed seed set on the female rows were harvested and carried into the next generations to isolate seedling lethal mutants that are closely linked with msg2 (Ramage, Wiebe, Eslick and Thompson, 1972). This material also segregated for various short-straw mutants. By F4 and F5, we had selected a number of short-straw mutants of sufficient promise as cultivars to warrant additional testing. At the same time, we had also obtained short-straw mutants from diethyl sulfate treatment of the cultivar 'Arivat'. None of the short-straw mutants induced in the pure line cultivar were worth considering as cultivars, or even as parental breeding material. When allele tested, many of the promising mutants from the segregating population were found to be allelic to the unacceptable mutants found in the pure line cultivar.

The conclusion drawn from comparisons of mutants selected in heterozygous and homozygous background genotypes was that the background genotype of a pure line is balanced to accommodate particular plant height genes. When the genes for plant height are changed, the background genotype is not the one that is needed for optimum expression of new genes. In the hybrid where the background genotype was highly heterozygous, a background genotype was selected that was more favorable to the expression of the short-straw genes. By selecting for short-straw in populations that were also segregating for background genotypes, we selected a "home" in which the short-straw mutants were reasonably "happy" and they responded by producing an acceptable short-straw plant.

Our observations of short-straw mutants selected in heterozygous and homozygous backgrounds may be used to explain in part the general failure of mutation breeding programs to increase yields. Most mutation breeding has been conducted using the best local cultivar as parental material. Such cultivars are reasonably happy hlmes for the combination of characters they must possess. When a character of a successful cultivar is changed through mutation, the mutant will probably not have the "happiest" home situation.

Professor Horst Gaul, now of Abteilung fur Pflanzengenetik der GSF, Grunbach, FRG, and his associates (cf. Gaul and Grunewaldt, 1971; Gaul, Grunewaldt and Hesemann, 1968; Lind and Gaul, 1976)

have studied the variation in character expression of several barley mutants in changed genetic backgrounds. They point out that most macro-mutations affect several characters, which can be morphological, biochemical or physiological; i.e., the mutants exhibit pleiotrophy. Gaul and his associates have transferred mutants into different genetic backgrounds and have shown that, through changing the genetic backgrounds of the mutants, the character expression of a mutant can be modified strikingly. Generally, it is the pleiotropic characters, when in the genetic background of the mother cultivar, that exert such an undesirable effect on the mutant phenotype that it prevents direct use of the mutant as a commercial cultivar. When the undesirable characters of a pleiotropic mutant are modified by transferring the mutant into different genetic backgrounds, many otherwise worthless mutants may be of practical value in plant breeding programs. In other words, a mutant induced in a pure line cultivar may not be of value in the mother cultivar, but may exhibit a phenotype of value when transferred to a different genetic background.

A consideration of "happy homes" in mutation work reminds us of some work done with isogenic lines. Professor Robert Eslick of Montana State University, Bozeman, Montana, USA, has produced isogenic lines by backcrossing the 2-row allele into 6-row cultivars and the 6-row allele into 2-row cultivars of barley. Commercial 2-row and 6-row cultivars differ in a number of characters such as tiller number, leaf size and rachis internode number. Most 2-row cultivars have a larger number of tillers, smaller leaves and culms and more rachis internodes than most 6-row cultivars. Because of more tillers and rachis internodes, 2-row cultivars produce almost as many seed per unit area as do 6-row cultivars and the seed is usually larger resulting in little difference in yield between 2-row and 6-row cultivars. Professor Eslick's isogenic lines are "6-row barley with a 2-row spike" and "2-row barley with a 6-row spike". Neither are worth very much. The 6-row barley with a 2-row spike, because of fewer tillers and rachis internodes, does not produce enough seed per unit area to yield very much. The 2-row barley with a 6-row spike produces more kernels than the existing leaf and culm area can handle, so the resulting shriveled seed reduces yields. It would be patently unfair to make a judgement concerning the worth of the 2-row and 6-row characters based on these isogenic lines. In their own genetic backgrounds, the genes are in a happy home; in the other genetic background, they are in an unhappy home.

This observation prompts us to urge caution in the use of isogenic lines to determine the worth of a particular character. When two contrasting characters are in the same background genotype, one is likely to be in a happier home than the other. The late Dr.G.A.Wiebe probably did more to promote the use of isogenic lines to evaluate the performance of different alleles than any other barley worker. He was aware of the danger of confounding gene action and the interaction of an allele with its background genotype and stated (Wiebe, 1968) "the answer must always be related to the specific background genotype in which the genes are measured". More recently, R.F.Eslick, another vigorous proponent of the use of isogenic lines, has pointed out (Eslick and Hockett, 1974) that "the worth of a gene may be completely obscured by pleiotropic or compensating effects, or both".

Consideration of the happy home concept has led us to reaffirm the division of plant breeding into two distinct phases: (1) generation of variation, and (2) exploitation of the variation. Success in both areas is dependent upon numbers; so, as we all know, plant breeding is a "numbers game".

In terms of generation of variability, we need to devise methods designed to select happy homes for the particular combination of characters that we are interested in. We propose that recurrent selection is the most feasible means of simultaneous selection for a character and its happiest home. Recurrent selection can be greatly facilitated by the use of genetic recessive male sterile genes. For several years we have practiced recurrent selection in Composite Cross populations that were also segregating for male sterility. Professor Eslick suggested that we stop referring to this procedure as "composite cross breeding" and call it "male sterile facilitated recurrent selection" (Ramage, 1975). Male sterile facilitated recurrent selection involves selecting large numbers of male fertile and male sterile plants from a population segregating for both the desired characters and male sterility, intercrossing the selected plants using male sterile plants as females, bulking the crossed seed and growing and harvesting the F_1 generation. The F_2 generation provides the population from which the next cycle of selection is made.

Male sterile facilitated recurrent selection has been used to produce a short-straw barley population from which lodging resistant cultivars and parents of hybrids may be selected. This population has been released to plant breeders as Composite Cross XXXII (Ramage, Thompson and Eslick, 1976). In our search for short-straw, lodging resistant plants, we developed four populations, each from a different source of short-straw. None of the four populations promised to be

an immediate source of acceptable lodging resistant cultivars. Large numbers of the four populations were grown in the winter at Tucson, Arizona. Short-straw plants, both male sterile and male fertile, were selected in each population and crossed with short-straw plants selected in the other three populations. All crosses were made on male sterile females. Crossed seed from each of the six cross combinations were bulked and planted at Bozeman, Montana in the summer. The F_1 was grown and combine harvested without selection. A large F_2 was grown in Arizona in the winter and short-straw plants were selected and intercrossed using male sterile plants as females. The crosses were bulked and planted in Montana in the summer. The F_1 was again grown and combine harvested without selection. Selecting short-straw plants in the F_2, intercrossing them using male sterile plants as females, bulking the crossed seed and growing and harvesting the F_1 without selection constitutes a cycle of male sterile facilitated recurrent selection in this program.

Selection was practiced, not only for short-straw, but also for such characters as tiller number, rachis internode number, glume size, awn shape and size, etc. To maintain as much heterozygosity as possible in the population, crosses were made between short plants that differed in other characters. By growing the F_1 generation in Montana, natural selection has produced plants that are adapted to being grown either in the winter in Arizona or in the summer in Montana.

Additional populations were established by crossing short-straw, male sterile plants selected from the original populations with various populations, lines and cultivars. The populations, lines and cultivars were selected to add germplasm for such characters as short-straw, large seed, and adaptation to the original population. Male fertile (both homozygous and heterozygous) short-straw plants were selected from the F_2's of nine populations and threshed in bulk to form Composite Cross XXXII-76. The male sterile facilitated recurrent selection program designed to produce a short-straw population will be continued. Additional germplasm will be introduced into the population. Whenever desired, future seed sources of Composite Cross XXXII will be produced by selecting from advanced generations of the populations contributing to Composite Cross XXXII-76 and from other populations involving different germplasm.

The next step in using male sterile facilitated recurrent selection to provide a happy home for barley characters involves crossing two populations that have been selected for different characters and recurrently selecting for the two characters simultaneously. This

should produce the happiest home for the interaction of the two characters. We are currently selecting for short-straw and large seed in a population obtained from crossing the short-straw population with a population selected for large seed. Also, we are simultaneously selecting for high tiller number and large number of rachis internodes in a population obtained by crossing two populations in which the two characters had been selected for separately. When we have obtained them, we will cross the short-straw, large-seed population with a high tiller number with a large number of rachis internodes. Simultaneous selection for all four characters will then be practiced. When intercrossing, a conscious effort will be made to cross individual plants that differ in characters other than the ones being selected for. This will help maintain heterozygosity in the background genotype. By selecting for characters in a genetic background that is kept as heterozygous as possible, desirable populations should eventually be obtained. These populations can then be exploited for either pure line cultivars or for parents of hybrids.

Recurrent selection is essentially what has been practiced with pedigree selection in conventional breeding programs in the self-pollinated crops (cf. Figure 1, Eslick and Hockett, 1974); i.e., two lines are crossed and a desirable line is selected from the progeny. Two such lines are then crossed and another desirable line in selected. This type of "recurrent selection" takes a minimum of about 10 years between cycles. By using male sterility to facilitate recurrent selection, we can speed up generation time considerably. More importantly, we can handle much larger populations of genes thereby improving our chances of selecting happy homes for barley characters.

REFERENCES

Eslick, R.F. and E.A.Hockett. 1974. Genetic Engineering as a key to water-use efficiency. Agric. Meteoroi. 14: 13-23.

Gaul, H. and J. Grunewaldt. 1971. Independent variation of culm length and spike internode length of a barley erectoides mutant in a changed genetic background. Barley Genetics II. Washington State Univ. Press, pp. 106-118.

Gaul, H., J.Grunewaldt and C.U.Hesemann. 1968. Variation of character expression of barley mutants in a changed genetic background. Mutations in Plant Breeding II. IAEA, Vienna. pp. 77-95.

Lindt, V. and H.Gaul. 1976. Studies of pleiotropic genes and their character complexes in erectoides mutants. Barley Genetics III. Karl Thiemig, Munchen. pp.171-180.

Ramage, R.T. 1975. Techniques for producing hybrid barley. Barley Newsletter 18: 62-65.

Ramage, R.T., R.K.Thompson and R.F.Eslick, 1976 . Release of Composite Cross XXXII. Barley Newsletter 19: 9-11.

Ramage, R.T., G.A. Wiebe, R.F.Eslick and R.K.Thompson. 1972. Use of mutagenic agents in hybrid barley breeding. Barley Newsletter 15: 72-78.

Wiebe, G.A. 1968. Breeding. In Barley, Origin, Botany, Culture, Winterhardiness, Genetics, Utilization, Pests. U.S.Dept.of Agric., Washington, D.C. pp.96-104.

POSSIBLE CHARACTERISTICS OF DROUGHT TOLERANT BARLEY

By

Hayden Ferguson*

Introduction

Plant breeders are completely aware of the fact that drought stress is the main factor limiting small grain production in much of the world. They are also aware that more of the world food production must come from semi-arid areas with very limited or no irrigation if the world-wide goal for increased food production and increased water use efficiency is to be realized. It is then, at first glance, a paradox that there are very few plant breeding programs specifically designed to increase the drought tolerance and the 'plant controlled' factors of water use efficiency of small grains. However, Burton (1964) and Irving (1966) have pointed out that breeders face tremendous obstacles in this regard and that if they are to make accelerated advances in breeding for drought tolerance-water use efficiency, then there will probably have to be significant inputs from other branches of science such as physiology, physics, etc. This latter group must define the specific reactions of different available morphological characteristics and devise simple and rapid techniques for the screening of possible drought tolerant characteristics of plants. Burton (1964) points out that, although breeders have made significant progress in the breeding for drought resistance and increased water use efficiency, there is urgent need to, through fundamental research, the plant characteristics responsible for these attributes. (Let it be emphasized that drought resistance and water use efficiency are not synonymous. The goal is to define those plants or plant characteristics that will allow maximization of usable food production whatever the drought status. Survival of drought is not adequate).

In this paper, we will examine the way in which some of the different available morphological features modify the way in which barley interacts with its environment and, thus, influences drought resistance and water use efficiency. Also we will examine possible measurement-screening techniques that may prove useful in selecting lines for improved water use efficiency.

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Morphological Characteristics

Many authors (Gates, 1965, 1962; Wolpert, 1962; Loomis, 1965; Reitz, 1974) have pointed out that different morphological characteristics can significantly modify the plant-environment interaction, and, in some cases, this modification is a major factor in plant survival in harsh environments. Numerous different morphological characteristics such as plant color, awn length, leaf width, plant type, plant height, and etc., are available in barley. Logical and in some cases mathematical analysis of possible plant-environment interactions suggest that some of these morphological features should affect the coupling of the plant with its environment and, thus, drought resistance and water use efficiency.

Although these different morphological features have been available for some time, few studies have been concerned with the influences that they might have on drought resistance. Two obvious reasons are: (1) equipment, including data acquisition systems, has not been readily available to make the necessary measurements, and (2) since the features were usually available in very different varieties, any evaluation of a particular feature had a great chance of being masked by gross genetic differences. The rather recent development and collection of lines of barley isogenetic or nearly isogenetic for particular plant traits should be a valuable tool to workers in the field. These lines allow specific and known characteristics to be isolated and evaluated.

Degree of Awning

A common observation of early workers was that awned small grains did better, especially in semi-arid environments, than awnless. One of the first studies using approximately isogenic pairs (Suneson et al., 1948) showed that awned lines were generally superior in yield and test weight. Workers generally atrributed this improvement to some pleiotropic effect. However, a logical analysis of the awn-environment interaction suggests that specific physical and physiological factors may be the cause.

Several years ago, we began a series of experiments using isogenetic material, to study the influence of awns on energy exchange and photosynthetic activity. We found that awns do significantly influence the plant-environment coupling. Canopies of awned barley lines, especially 6-row types, were significantly cooler than their awnless isogenics. At the same time, the awned lines absorbed more energy as net radiation. At first glance this would indicate that the cooling was a result of increased evapotranspiration (ET) because of the higher heat load. But, measurements on plants with no ET also showed a lower temperature with the awned

lines. Field measurements (Benci, et al. 1973) showed that awned canopies lost significantly more sensible heat through conviction and conduction than did awnless lines and this process accounted for the lower canopy temperatures. As a rule, lower canopy temperatures should indicate less latent heat loss.

Data also indicate that awns are effective photosynthesizers. We compared the photosynthetic activity of spikes of pairs of isogenetic barley lines over the period of seed development from initiation to maturity. The data consistently showed that awned spikes maintained a high positive net photosynthetic activity until about 0.9 of seed maturity. Awnless spikes dropped below zero net photosynthesis at or before 0.5 of seed maturity; thus, the carbohydrates for seed development had to come from below the spike.

The importance of this is that, in general, leaves tend to senesce much quicker than awns under drought stress. It is not unusual under stress conditions from drought or disease to have most of the leaves gone during the kernel filling stages; in these cases awns have even more significance.

It should be emphasized that awns present a tremendous surface area for water evaporation and under conditions where sensible heat transfer is small - very warm air temperatures - they could be disadvantageous to water use efficiency. Moreover, Johnson et al., (1974) indicate that rates of photosynthesis and transpiration between awns and leaves do not differ with regard to water stress. However, based on the accumulative data available, we conclude that awns are beneficial to small grain production in semi-arid areas.

Plant Color

A reduction in net radiation of a plant canopy should result in a reduction of transpiration and several workers (Gates, 1965; Seginer, 1969, and Doraiswamy and Rosenberg, 1974) have suggested that increased reflection should be a viable means of decreasing net radiation. Since the amount of radiation normally reflected from crops is relatively small, a very real possibility for increasing the reflectivity appears to exist. The benefit of such an increase appears high. Seginer (1969) predicts that a 15% increase in reflection might cause a 30% reduction in both net radiation and water use.

There is available in barley a broad range of plant colors; using isogenic pairs we have evaluated the influence of colors on canopy temperature, shortwave reflection, net radiation and pattern of water use. The light colored lines are significantly cooler, especially on bright days, than the normal lines. This decrease in temperature occurs because of significantly more reflection and less net radiation. With one line, Liberty, we found that the golden osogene reflected an average of 6% more shortwave radiation over the season than the normal isogene. In terms of water use, this would amount to, over the season, (in theory) a difference of 4 cm of water; a very significant amount under semi-arid conditions. Because of advection and possible differences in canopy resistances, one would expect the actual difference to be less, but the promise is there.

Actually, under semi-arid conditions, the crops generally use all available water. However, an increase in reflection-decrease in net radiation should result in a change in the pattern of water use. For instance, relative less water use early in the season would result in more water being available during the critical kernel filling stage. Our field data indicate this to be the case.

One of the problems with high colored, high reflecting lines is that they tend to contain less chlorophyl and are, thus, less productive. However, we have one isogenic pair, Liberty, in which the light consistently outyields the dark line.

We do conclude that the breeding of lines with significantly increased reflection, probably through color but perhaps through waxes, holds real potential as a plant adaptive characteristic for semi-arid environments.

Root Proliferation

The density and degree of extension of roots should be a significant factor in the survival and production of plants under semiarid conditions. A root system that is extending into soils of higher water potential (closer to zero) continues to make water available to the plant. Roots are difficult to study because of the obvious physical problem of visibility and sampling. However, Hurd (1974) and his group have been successful in breeding for more extensive root systems in spring wheats and have, thus, developed varieties that have provided high yields under moisture stress conditions. We (Ferguson et al. 1969) have shown that there are significant varietal differences of winter wheat in the ability to extract water from all soil depths to about 2 meters and especially in the critical zone below 60 cm. The varieties that could best extract this degree of water have, in general, been the best in the semiarid plains of Montana.

Thus, there is every reason to believe that the breeding of barleys with more prolific root systems would be advantageous for semiarid areas. We have found considerable varietal differences between barleys in their ability to extract water from various soil depths but have not used this information in breeding programs as yet.

Other Morophological Features:

Since most of the water lost by transpiration is through open stomata, they have often been considered a key to the development of drought tolerant varieties However, most of the work in this regard has been frustrating. Environmental factors often appear to have more control over stomatal number and size than does genetics. Kaul (1974) found that the stomata spring wheat showing good drought tolerance were more sensitive to water stress but it is the authors experience that this is not always the case. Certainly more work is needed but this does not appear to be the most promising area for significant progress.

Leaf size should be an important factor in the partitioning of heat load between latent and sensible heat exchange. In general, the best dryland varieties of barley in Montana have narrow leaves. The narrow leaves allow more light penetration to the lower portions of the plant canopy and, thus, the lower leaves tend to remain functional for a longer period of time . We have found, in general, that narrow and midwide (normal) isogenic lines of barley have somewhat better water use efficiency. Also, our data indicates that canopies of narrow leaves tended to be cooler but not significantly so.

Moss et al. (1974) have listed many other morophological characteristics that are probably aminable to genetic regulation that might modify the drought tolerance - water use efficiency of plants. In barley (or other small grains) most of these have not been studied sufficiently to make even general comments as to their possible beneficial contributions. In theory; however, many of them for instance leaf hairs, offer considerable promise.

Screening Techniques

Eslick and Hockett (1974), among other, have pointed out that "tests for characteristics contributing to water use efficiency must be simple and rapid for application to thousands of individual plants in a relatively short period of time". Certainly, no single test is currently available. Considering the complexity of the plant response-environmental interaction it is doubtful that any single test will ever be satisfactory, Hsiao and Acevedo (1974) point out that breeders and their associates working in the area of water use efficiency-drought tolerance must avoid the "pit falls

of concentrating solely on one or two physiological tests, no matter how sophisticated or eccentric". Nonetheless present knowledge on plant physiological responses and measuring techniques suggests that some combination of simple plant tests should be devisable that would greatly accelerate the breeding of plants for semiarid areas .

Plant Water Potential Measurements

Total plant water potential Ψt, is of great importance in determining plant growth, physiological responses, stomatal responses and soil water absorption by roots. More over it is easily measured with the pressure bomb or on, intact leaves, with a thermocouple psychrometer. Without minimizing the importance of Ψt measurements in studies of plant responses Ψt measurements in studies of plant responses, Ψt varies so tremendously with environmental conditions that there is little likelihood that it, by itself, will be of much use in selection of drought tolerant lines.

Plant osmotic potential, Ψop, is much more conservative than Ψt; that is, it is not so highly related to environment conditions and appears to be more of a genetic controlled factor. We have found significant and consistant differences in the Ψop of barley varieties. Also Ψop is a major factor in determining cell turgor and one might expect plants with high Ψop to be more drought resistant. Osmotic potential is easily measured with a thermocouple psychrometer and appears to be one of the measurements that holds promise as a means of selecting drought tolerant lines.

Using water potential measurements one can calculate the modulus of elasticity of plant cells (Wilson, 1967). It is somewhat a laborious procedure and, thus, does not lend itself to the evaluations of many lines. However, our preliminary data indicates that the techniques may be useful in differentiating between varieties relative to drought tolerance.

Physiological and Methabolic Measurements

Hsiao and Acevedo (1974) have shown that minute changes in plant growth occur very quickly when plants are stressed. Procedures of making such measurements do not lend themselves to rapid and large scale screening techniques.

Proline accumulates in plants subjected to water stress (Boggess, et al, 1976) and differences in proline accumulation may be a possibility in differentiating between resistant and susceptible lines. This approach warrants more work but at this time definitive statements as to the use of proline in a screening technique is unknown.

Stomatol measurement, including number, size and aperture opening, have not, in general, been easily related to drought tolerance. However, considering the importance of stomatal response to transpiration, such measurements may well be important in many cases. The stomatal diffusion pyrometer (Knoemasu, et al., 1969) is a useful tool for studying the influence of water stress on stomatal reactions.

Root Growth Measurements

Root chambers of some type have been used by many workers, including Hurd (1974), to study root mass and length. Such equipment is useful but expensive. For some time we have been using soil water extraction from wet soil profiles to estimate root growth. In differentiating between varieties, such a procedure gives an approximately integrated estimate of active root density and length. It is certainly not as accurate as actual root measurements but is much easier and cheaper to use. Soil water content measurements can be made by physical sampling or with neutron equipment. Some type of root extension measurement may be one of the important measurements that can be made to differentiate varieties as to possible drought tolerance.

Desiccation Resistance

Among the simplest measurements that can be made that may be useful in selecting drought tolerant varieties, is a measure of the water content of excised plants or leaves The method consists of measuring, by weighing, the water content of plantd as a function of time Several workers (Salin et al., 1969 and Dedio, 1975) reported that they were able to differentiate between varieties with this technique.

Another promising method for differentiating between varieties as to desiccation resistance, and presumably drought tolerance, is to determine the influence of heat shock on the leakage of ions from cells by measuring the electrical conductivity. Sullivan and Eastin (1974) and co-workers have found this technique useful in differentiating between heat tolerant sorghum varieties. It is very rapid and thus can be used to screen large numbers of plants.

Summary

In this very cursory review we have pointed out some of the morophological features and measurement techniques that may be possible means of developing barley varieties with greater drought tolerance-water use efficiency. Data on some of the morophological features is rather definitive:

extensive root systems are generally beneficial for production under semiarid conditions, awns are generally beneficial, plants that could somehow reduce their own heat load without harming yield would be advantageous. In the inclusion of these or any other morophological features in a breeding program, one must always be aware of the necessity for genetic compatability. Ramage (1974) has entitled this the "happy home" concept. Measurement screening techniques are less understood; however, the possibility of finding some combination of measurements that will allow for at least gross selection of tolerant lines is certainly worth extensive study.

References

Benci, J.F., J.K.Aase and A.H.Ferguson. 1973. Aerodynamic and energy balance comparisons between awned and nonawned barley. Agron.J.65:373-377.

Boggess, S.F., C.R.Stewart, Dan Ospinall and L.G.Paleg. 1976. Effect of water stress on proline synthesis from radioactive precursors. Plant physiol.58:398-401.

Burton, Glenn W. 1964. The geneticists role in improving water use efficiency by crops. Research on Water, ASA Special Publication 4: 95-103.

Dedio, W. 1975. Water relations in wheat leaves as screening tests for drought resistance. Can.J.Plant Sci. 55: 369-378.

Doraiswamy, P.C. and N.J.Rosenberg. 1974. Reflectant induced modification of soybean canopy radiation balance. I.Preliminary tests with a kaolinite reflectant. Agron.J.66:224-228.

Eslick, R.F. and E.A.Hockett. 1974. Genetic engineering as a key to water-use efficiency. Agric.Meteorol. 14:13-23.

Ferguson, Hayden, P.L. Brown and D.W.Fryrear. 1970. Evapotranspiration and root growth. Great plains Agricultural Council Publication No. 50: 255-274.

Gates, D.M. 1962. Energy exchange in the biosphere. Harper and Row, New York, N.Y.

Gates, D.M. 1965. Radiant energy, its receipts and disposal. Meteor. Monographs 6: 1-26.

Hsiar, Theodore C. and Edmundo Acevedo. 1974. Plant responses to water deficits, water-use efficiency and drought resistance. Agric.Meteorol.14:59-84.

Hurd, E.A. 1974. Phenotype and drought tolerance in wheat. Agric. Meteorol. 14: 39-55.

Irving, George W., Jr. 1966. Frontiers of agricultural research to meet U.S. needs. Winter meeting of the American Soc. of Agric.Engineers, Chicago, Illinois. December 9.

Johnson, R.R., N.M. Frey and Dale N.Moss. 1974. Effect of water stress on photosynthesis and transpiration of flag leaves and spikes of barley and wheat. Crop Sci. 14:728-731.

Kanemasu, E.T., G.W.Thurtell and C.B.Tanner. 1969. Design, calibration and field use of a stomatal diffusion pyrometer. Plant Physiol. 44: 881-885.

Kaul, R. 1974. Potential net photosynthesis in flag leaves of severely drought-stressed wheat cultivars and its relationship to grain yield. Can J.Plant Sci. 54: 811-815.

Loomis, Walter E. 1965. Absorption of radiant energy by leaves. Ecology 46: 14-17.

Moss, D.N., J.T.Woolley and J.F.Stone. 1974 Plant modification for more efficient water-use: The challenge. agric meleorol. 14: 311-320.

Ramage, R.T. 1974. Techniques for producing hybrid barley. Barley Newsletter Vol. 18: 62-65.

Reitz, L.P. 1974. Breeding for more efficient water-use - Is it real or a mirage ? Agric.Meteorol. 14: 3-11.

Salim, M.H., G.W.Todd and C.A.Stutle. 1969. Evaluation of techniques for measuring drought avoidance in cereal seedlings Agron.J.61:182-185.

Seginer, I. 1969. The effect of albedo on evapotranspiration rate. Agric.Meteorol.6:5-31.

Sullivan, C.V. and J.D.Eastin. 1974. Plant Physiological Responses to water stress. Agric. Meteorol. 14: 113-127.

Suneson, C.A., B.B.Boyles, and C.C.Fifield. 1948. Effects of awns on yield and market qualities of wheat. USDA circular No. 283.

Wilson, J. Warren. 1967. The components of leaf water potential. Asst.J.Biol.Sci. 20: 329-347.

Wolpert, Arlen. 1962. Heat transfer analysis of factors affecting plant leaf temperature. Significance of leaf hair. Plant Phys. 37 113-120.

SHORT SEASON BARLEY BREEDING

By

E. I. Kivi *

1. Introduction

Barley is cultivated further north than any other cereal. North of the 60th parallel, the earliest varieties of barley mature from 10 to 20 days earlier than those of wheat or oats. The reliability of barley is improved by the fact that it developes relatively faster than the other annual cereals in cool growing seasons. In the North, too, barley is an ancient agricultural crop. Over centuries of cultivation, early ripening local types evolved, from which the early results of selection breeding for six-rowed cultivars are still some of the earliest barleys known. Breeders have not managed to overcome this earliness threshold, and the improvements made have been directed at other characters. Advances in yielding capacity have often been made at the expense of early maturity.

Short vegetative period (on the 60th parallel from the beginning of May to the end of September) and low temperatures (average for the warmest month, July, about +17°C) are the main factors determining the productivity of crops. Primarily because of very long days and high levels of radiation energy during the first half of summer (day length in June 18.7 h/d), plants develop so rapidly that barley varieties which in the maritime parts of Europe or in the Mediterranean winter need 120-140 days from emergence to maturity, in the southern parts of Finland (at latitude 60°N) require only about 90 days.

Under these circumstances, six-rowed barleys (*Hordeum vulgare* conv. hexastichon) have always predominated in the North. At the end of last century, when only local barleys were in cultivation, the proportion of six-rowed land races was 80 percent. Of the present barley area of Finland comprising altogether 500,000 hectares, the proportion seeded to six-rowed varieties is still 80 percent. All in all, scientific breeding work has not influenced the balance between the two types of barley.

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Nevertheless, two-rowed barleys have certain advantages over six-rowed types: the former have better grain quality, and they are less subject to straw breakage and other injury at the dead ripe stage. Even as far north as 60°N, many two-rowed varieties both outyield six-rowed ones and mature sufficiently early even in cooler seasons.

The reason for the popularity of the six-rowed varieties is their rapid developmental cycle adapted to northern climatic conditions with a short and abruptly ending vegetative period. Even by September temperatures may fall to levels which disturb the maturing of the kernels. Normally, early varieties of six-rowed barley ripen at least fourteen days earlier than two-rowed varieties. In a northern climate, the small kernel of six-rowed barley is an advantage in spite of the fact that the grain quality does not reach the level required for two-rowed malt barley. Many farmers emphasize the fact that by growing six-rowed barley they can extend the cereal harvesting period and that six-rowed barleys are the only crop early enough to precede an overwintering crop like winter wheat.

2. The gene source of six-rowed barley

With very few exceptions, the primary source of breeding material for six-rowed barley consisted of the Northern European land races. This applies equally to two-rowed and six-rowed material. During the initial stages of scientific breeding work, breeders succeeded in selecting from the widely variable local barleys several very early cultivars. The most widely grown of these was Olli released exactly 50 years ago. Olli spread in Canada, too. It is still grown there and was used as a source of earliness in breeding the North American smooth-awned variety Gateway.

Finnish barley breeding has been characterized by an effort to develop both six- and two-rowed varieties with a wide range of environmental adaptation. One reason for this is the generally high acidity of our soils. In the international plant breeding handbooks, certain old Finnish barleys are still cited as examples of the most acid-tolerant varieties known. A quadrupling in barley production and almost a tripling in the barley acreage over the twenty year period since World War II has been made possible only by virtue of varieties with low growth requirements. Such varieties, however, have not altogether met the demands of modern agricultural practice with its higher rates of fertilization and more efficient fertilization techniques.

In Finnish barley breeding, a kind conservatism prevailed for a long time; the gene pools of six- and two-rowed types were kept strictly separate from each other. Only rather recently have varieties been released in which the gene-flow has been opened from distichon to hexastichon barleys, or vice versa. Our colleagues in Sweden have devoted their efforts to improving the earliness of two-rowed barley by using extremely early maturing six-row varieties in their crossing programmes (e.g. K.Wiklund, Y.Horberg). In Finland breeding work has been aimed at extending the agricultural possibilities of six-rowed barleys by widening their genetic variability with the two-rowed genome (O.Pohjanheimo, R.Manner, M.Rekunen, E.Kivi).

This paper deals with the results obtained in the breeding programmes outlined above, and with the problems which arise when we try to breed modern varieties of feed barley for the Northern climate. The problems associated with utilizing six- x two-rowed crosses are not new in plant breeding research. Very recently, the theoretical basis of this breeding sector has been carefully investigated by a group of Japanese workers (1). Here, the subject will be reviewed in the context of practical plant breeding.

3. The yield components of six-rowed barley

The yields of two- and six-rowed barleys are largely determined by different components. In an investigation made at the University of Helsinki, these components were examined in growth chamber tests with temperature and plant density as variables (2). The several varieties tested included a typical early maturing six-rowed barley (var.Tammi) of multi/multi origin, and a two/two-type barley (var. Arvo), which under normal field conditions matures approximately 20 days later than Tammi. Both are Finnish breeds. In regard to their reactions to the variables for which the varieties were tested, several differences emerged (Fig.1).

The tillering capacity of the six-rowed barley is much lower than that of the two-rowed (A) but the number of grains per ear is very much greater (B). Thus the most important yield component of the six-rowed barley is the number of grains in the ear of the main tiller, while that of the two-rowed type is a high tillering capacity. A fortuitous combination of these two characters might well be conceived as the dream of research workers studying the practical possibilities of multi/two segregates (1).

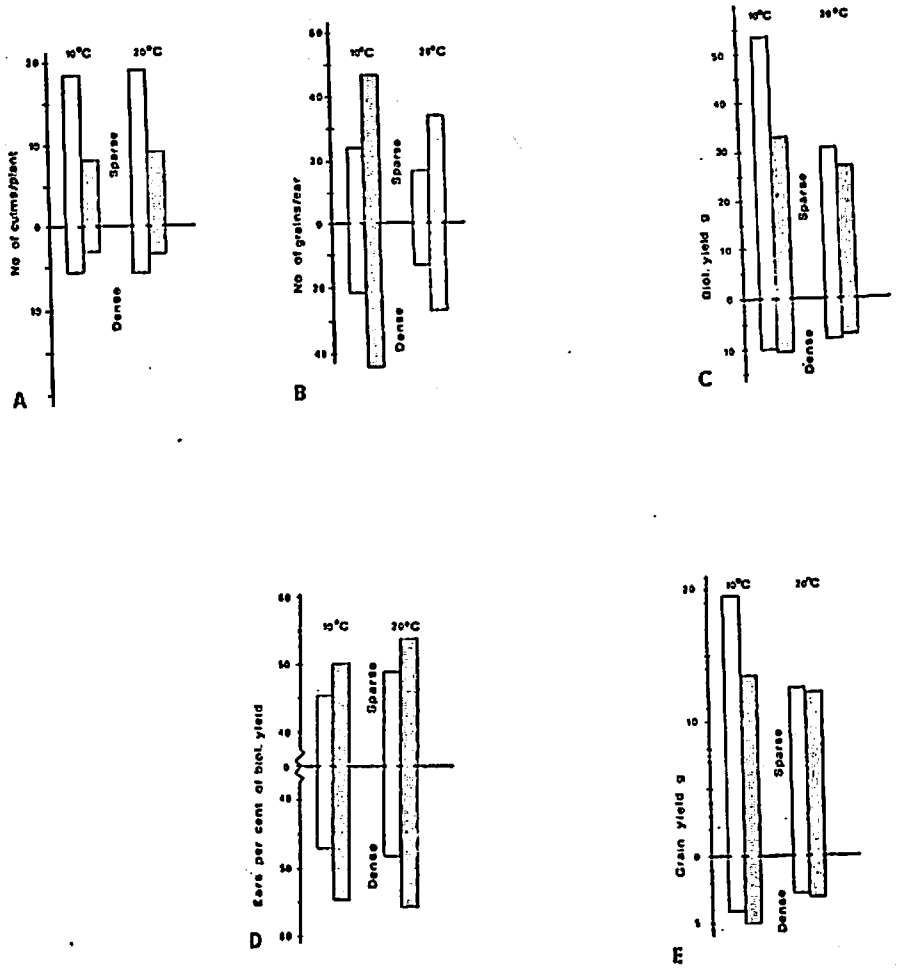

Fig. 1. Yield components of the early maturing multi/multi six-rowed barley Tammi (shaded) and the late-maturing two-rowed variety Arvo (open) in a growth chamber trial (2). Two temperatures (+10° and +20°C) and two stand densities (sparse 3, dense treatment 13 plants per pot) used as environmental variables. Details in text.

Under the cooler conditions favouring slow growth, the total biomass of two-rowed barley is significantly higher than that of six-rowed barley. An increase in temperature depressed the amount of growth of Arvo barley so that at 20°C both barleys produced an equal biomass. The proportion of ears in six-rowed barley is higher under all conditions (D).

The stronger growth of two-rowed barley under cool conditions is reflected also in grain yield (E). Throughout the temperate regions where the precipitation is moderately high, this character accounts for the predominance of the two-rowed barleys with their rather long growing time but also high yield potential. Grown at high temperatures, two- and six-rowed barleys produce equal yields.

Because of its rapid growth, six-rowed barley is well adapted to short season conditions. In addition, it might have wider adaptation to environments differing e.g. with regard to temperature than the two-rowed type has. On account of these characters, six-rowed barley may be highly suitable as a winter crop in the southern areas of barley production and also as one component of a multicrop scheme.

4. The practical possibilities of multi/two-varieties

The first Finnish barleys originating from crosses between six- and two-rowed varieties are of multi^2/two type. For most characters they are very close to ordinary multi/multi barleys, because the final cross was made between two six-rowed lines, only one of which had two-rowed barley in its parentage. In straw-stiffness the crosses show an improvement over the six-rowed type (Fig. 2). Also the yielding capacity has been increased and some of these have consistently yielded better than other varieties. A tendency towards decreased protein contents seems to be typical of the multi/two type of barley (1). In these multi^2/two varieties, there can be seen a trend towards higher growth requirements (Fig. 3). Their yielding capacity is at its best under conditions optimal for high barley yields.

When the first ordinary multi/two varieties of six-row barley were released a great advance in straw stiffness resulted (Figs. 2 and 4). These varieties tolerate, indeed utilize, intensive fertilization but they also need good growing conditions. Compared with the old multi/multi varieties, they have a rather narrow range of adaptation. These varieties could well respond to irrigation,

which in the North, however, is seldom used in cereal production. Multi/two varieties are normally late maturing owing naturally to the long growing time of the two-rowed parent. In any case, with this type of six-rowed variety we have reached the same high level of straw stiffness which here in north Europe has been incorporated into two-rowed material through cross-breeding with straw-stiffness mutants.

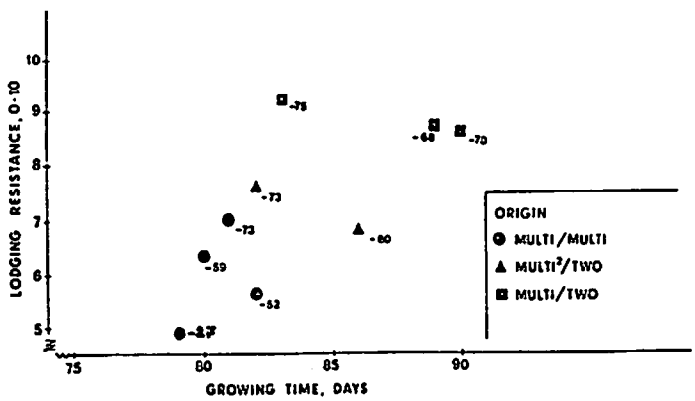

Fig. 2. Change of growing time and straw stiffness for six-rowed barley varieties of multi/two origin compared with some multi/multi barleys. The lodging resistance has been improved but the maturity delayed.

In one instance, a breeder has succeeded in selecting from a multi/two population a variety with a higher resistance to straw breakage at the dead ripe stage than six-rowed types usually possess. In the present varieties of six-rowed barley, a tendency to straw breakage when combine harvesting is used lowers the reliability of the crop.

The greatest advantage achieved with multi/two barleys is thus the improvement in characters important in modern intensive barley production, but the earliness of the old multi/multi barleys has been largely lost.

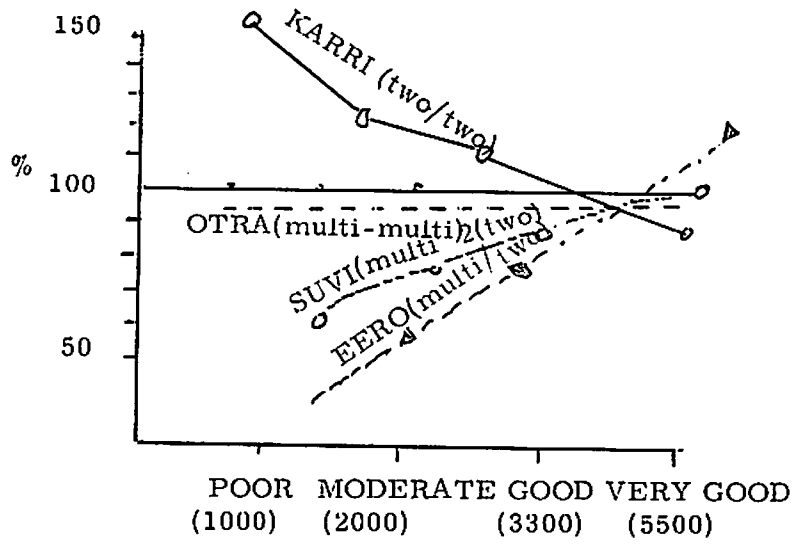

Fig. 3. The relative yielding ability of barleys of diverse origin at different levels of cultivation intensity. The 100 level represents the average yield of the barley crop based on the trial results of a large number of varieties. Varieties with a sharply rising yield curve have high growth requirements, whereas two-rowed Karri is a variety with very low growth requirements. Mainly because of its weak straw, Karri is unable to compete at high yield levels. From unpublished results of Mr. M. Rekunen, employing the calculation methods of (3).

5. The early-a^8 factor of Mari barley in a multi/two background

The two-rowed Svalov variety Mari is an early-a^8 mutant of Bonus, and has been used as a parent of a Finnish multi/two variety (Fig. 2). When the early-maturing Mari was crossed with a very early six-rowed multi/multi variety, transgressive segregants for earliness were found in the resulting population. From this population we have already selected a new variety (Hankkija's Eero) which is very stiff strawed, and earlier than the multi/two varieties based on Bonus itself (Fig. 4). This crossing programme is a first-class example of how an induced mutation can be used by transferring it to another genemilieu, in this case to a very foreign one.

The variety Eero derived from Mari is a typical multi/two variety because its growth requirements are high and its environment tolerance narrow (Fig. 3). It is a transgressive variety, if not for earliness, then for shortness and stiffness of straw. It stays short even at the highest latitudes of crop production where most barleys react to the extreme daylengths by growing too tall and lodging badly.

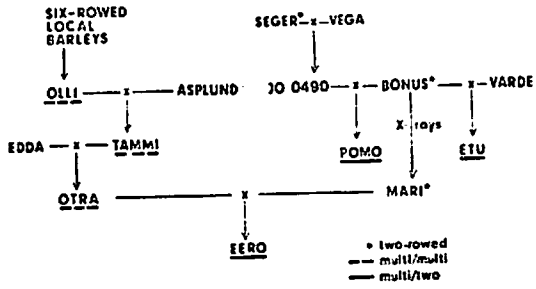

Fig. 4. Origin of certain six-rowed barleys grown in Finland (broken and solid underlining).

6. Transferring high-lysine genes into six-rowed barley

The use of multi/two crosses in breeding work also allows the exploitation of certain valuable genes, such as resistance genes, only present in two-rowed material. The occurrence of harmful barley diseases and resistance breeding against them has not, at least until now, presented so great a problem at northern latitudes as further south.

Nevertheless, a very important breeding objective is to improve the protein yields of six-rowed barley by transferring protein genes, such as hilly factors, by means of multi/two crossings. When we have used two-rowed Hiproly barley in such crosses, we have comeup against a negative relationship between

protein content and yielding ability similar to that encountered by most breeders working in this field. However, the more advanced crosses have already yielded some multi^2/two lines with a high lysine content and at least satisfactory yielding ability.

At our breeding institute we have a rather extensive breeding programme in progress with so-called Risø lysine mutants. One example of this programme involves Risø 1508 x Tammi crossings with two backcrosses to the six-rowed parent with Risø as donator (Fig. 5). By September 1977 we shall have three stages of multi/two material in the first screening for protein quality. We aim to isolate that fraction of the variability in which the lysine factor has been transferred to the six-rowed barley type.

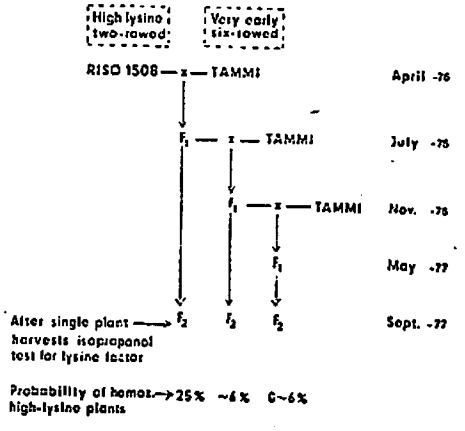

Fig. 5. A back-crossing programme for transferring the Risø 1508 lysine factor to early six-rowed barley. The protein screening takes place according to (4) adapted for isopropanol treatment by Danish researchers (Miss K. Pellinen, unpublished breeding programme).

7. Perspectives

The two-rowed segregates originating from the two-rowed by six-rowed crosses possess neither the same level of earliness nor the yielding capacity as their six-rowed siblings. The poorer tillering capacity resulting from the use of six-rowed parents in the

crosses is aggravated by the northern climatic factors, which accelerate the growth of the barley plant and limit its tillering potential. It thus seems that in the future, breeding efforts will be centered on the six-rowed multi/two barleys.

We have already succeeded in developing high-yielding, six-rowed multi/two varieties which fulfill the demands of highly intensive cultivation. Most of the losses in earliness have been recovered by incorporating the earliness allele from two-rowed Mari.

The immediate future will provide the answer to the question of how to transfer successfully the lysine genes to six-rowed barleys. There are certain grounds for optimism, particularly since the grain quality demands for the northern six-rowed feed barleys are usually lower than for two-rowed varieties. Nevertheless, the biochemical obstacles and interrelations are similar for both six-rowed and two-rowed high-lysine barleys.

To augment our efforts in breeding for earliness, which will always be a major objective in northern cereal breeding, we have built up further breeding programmes around the multi/two barley Eero. We have made crossings between Eero and various multi/multi sources of earliness. Eero itself has been treated with the mutagen sodium azide, NaN_3, to induce early mutants of it with a similar growth type. In summer 1977 the F_2 and M_2 generations will be grown in a northern trial field at latitude 65°N., where the environmental conditions impose rigid selection for both earliness and straw characters.

References

(1) Takahashi, R., Hayashi, J. and I. Moriya. 1975. Barley Genetics III.

(2) Ayravainen, K. and Paatela, J. 1974. J.Sci.Agric.Soc. Finland, 46.

(3) Finlay, K.W. and Wilkinson, G.N. 1963. Austral.J. Agric. Res. 14.

(4) Rhodes, A.P. 1975. J.Sci.Food and Agric.26.

RESEARCH PROGRAMS AND NURSERY SYSTEMS

CONSTRAINTS OF BARLEY IMPROVEMENT IN THE NEAR EAST AND NORTH AFRICA AND SUGGESTIONS FOR IMPROVING THE PROGRAMS

By

Youssef Y. Klaimi *

INTRODUCTION

Barley, after wheat, is the most important cereal in the Near East and North Africa occupying approximately 9.5 million hectares and producing about 10 million tons of grain a year. The area, production and average yield of wheat, barley and total cereals in most countries of the Near East and North Africa are given, for comparison, in Table 1 extracted from the Near East Statistical Director, 1975. (The figures for Turkey were obtained from another source).

It appears from the table that wheat covers 59.5% and produces 55% of the total cereals The relative figures for barley are 17% and 15.1%, respectively. Compared to wheat alone, the area of barley becomes 28.6% and its total production 27.5% of those of wheat.

Table 2 shows the relative importance of barley in the same countries. The largest barley-grown areas are in Turkey, Morocco and Iran with approximately 2.5, 2.0 and 1.3 million hectares, respectively. But there are also other important barley-growing countries in the Region such as Syria, Algeria and Iraq with over half a million hectares grown every year in each.

Examination of the average yield figures (Kgs/ha) indicates that this average varies tremendously from one country to the other and is a little over one ton per hectare over the entire region. To the exception of countries where barley is grown totally or partially under irrigation, the average yield in some other countries can go drastically below the regional average reaching sometimes a low figure of 500 kgs/ha or less.

Table 3 compares the average yield of barley in the Near East and North Africa with the world and other regional averages. It is clear that the world and most regional averages are much higher than that of

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the Near East and North Africa; some of them being more than two items higher (N.C. America and Developed Region), others being about three times higher (Europe). This clearly shows an immense scope for barley improvement in the Region.

Constraints of Barley Improvement and Production

Having observed that the yield of barley is still maintained at a low level, it is of importance to try to investigate the reasons for this low yield, to define the main constraints of barley improvement and to work out some suggestions for improving the overall programmes in order to increase the barley production in this Region.

Yield being the outcome of genotype-environment interactions, the increase of production of any crop plant, including barley, requires two main prerequisites: 1) the identification and/or development of suitable varieties adapted to the prevailing conditions and possessing a high yield potential. 2) The provision of inputs necessary for the release of this potential yield. It is unfortunate that neither the one nor the other of these prerequisites have been fully realized with respect to barley, some of the reasons for this are discussed below:

Crop Improvement Programme

In most countries of the Region the barley breeding programmes have not been aggressive or dynamic enough with the result that the progress achieved in improving the crop from the genetic stand point is not yet of any great significance. It should be recognized that some breeding work is being, and has long, been carried out and that many countries of the Near East and North Africa now dispose of improved varieties of barley which are somewhat higher yielding than the old native or traditional cultivars. Nevertheless, the turn-over of new improved varieties has been very slow and the varieties, now in hand, do not fully respond to the environmental needs. For the irrigated areas, for example, we are not yet in possession of real stiff-strawed barleys resistant to lodging under irrigation and high fertility conditions which are the prerequisites for high yielding in these environments. As to the rainfed areas, the situation is not any better and the newly developed varieties are not always significantly higher yielding than the local ones traditionally adapted to these conditions.

The reasons for this slow progress in the breeding programmes are many:

1) The number of well qualified and well trained barley breeders at anyone station is always very low and does not even compare with the number of wheat breeders (already low itself) present at the same station.

2) Because of the lack of trained personnel the genetic and breeding material handled at anyone time is not large enough to allow a rapid turn-over of new improved varieties.

3) The barley crop has always been neglected by the breeder, agronomist, plant pathologist and other plant scientists in favor of other crop species.

4) In most research institutions wheat and barley form one unique programme and the wheat breeder and/or agronomist is also responsible for the work on barley. Because of the greater economic importance of wheat in the Near East and North African countries, a much greater emphasis is placed on this crop and only little and casual attention is given to barley.

A phenomenon of common occurrence happens almost every year, for example, during the crossing season. Crossing usually starts in barley because of its greater earliness in comparison to wheat but is almost completely abandoned by the team whenever similar work need to be initiated in wheat The result is that the number of crosses made in barley at a given breeding station is always much lower than the one achieved in wheat even where barley is a relatively important crop.

Production Agronomy Programme

What has been said about the crop improvement programme can be extended to the production agronomy programme of barley. In this field also there is a great shortage of well qualified and experienced research scientists to plan and implement inter-disciplinary research projects aimed at finding out solutions to practical problems.

There is very little or no motivation to attract and encourage good research workers due to low salary scales, poor working conditions, little understanding on the part of administrators and many sources of frustration: financial, social and otherwise. Links are also very weak between researchers and planners and there is a general reluctance on the part of specialists to work together as a team and to cooperate towards the achievement of the common goal of raising crop productivity.

Because of the absence of inter-disciplinary approach the results achieved have emerged from isolated and disconnected programmes and efforts and have seldom been planned and conceived with a production-oriented objective. Also, these results have sometimes been extrapolated from similar work on wheat or most often obtained under special agro-climatic and cultural conditions within the confines of the research institution, with the outcome that they have often failed to achieve the required success when brought to the farmers fields.

Seed Certification and Extension Programmes

One of the criteria for increasing production is the establishment of an efficient seed production and distribution programme which will insure delivery of certified seeds of improved varieties, and in sufficient amounts, to the farmers. Such programmes are, unfortunately, lacking in many countries of the Region and this constitutes a real constraint to increasing barley production. Even where such programmes exist, it has often been observed that the multiplication of a new improved variety takes a number of years to build for a sizeable amount of seeds for distribution to the farmers. During the process it may also happen that, before a new variety is actually released, another one is identified resulting in the suspension of the seed multiplication of the first and initiation of the seed multiplication of the other.

As to the extension programmes in the Region, it has become well-known that these programmes are weak, inadequate, poorly staffed and loosely linked with the research and with the farmers. As a result of these weaknesses, many of the good research findings remain in the files or are seldom put into real practice for operating the necessary impact on production. Where this transfer of knowledge from the research institution to the farmers fields has been tried the results have not always been spectacular because of the limited applicability of the scientific finding itself or because of the meagre knowledge of the improved technologies on behalf of the transferring agent.

Production Programme

In addition to these many constraints limiting barley production in the Near East and North Africa and related to the crop improvement, production agronomy, seed certification and extension programmes, there are also other major constraints encountered at the farm level.

The barley crop has not only been neglected by the plant scientists in the Region but also by the farmers themselves and these neglects are inter-dependent. Because of low return, the farmers have always considered barley as a poor crop and dealt with it as such, reserving for it the poor land, shallow or saline soil s and inappropriate cultural managements. The barley fields are rarely, if ever, fertilized even where the varieties used can stand some fertilization, they are irrigated only if water is abundant and no other crops on the farm requires irrigation, and they are sometimes grazed when the livestock need some green fodder.

When seed of improved varieties are available they are seldom utilized in association with the required package of improved technologies. This is the common practice in small farm holdings, and extends also to wheat and other cereals, because small farmers are not financially capable to supply the necessary inputs for maximizing production (field equipment and machinery, good soilned preparation, certified seed, adequate fertilization, chemical weed control, irrigation water, storage facilities, etc.).

All these constraints from various causes, in addition to the extensive use of the cereal-fallow rotation which is a wasteful practice of losing about 50% of the land every year, have resulted in an extremely low yield output of barley per unit area necessitating short and long-term measures to be taken at various levels for improving the present situation.

Suggestions for Improving the Programmes

Crop Improvement Programme - we have observed (Table 1) that the average yield of barley over the entire Near East and North African Region is about 96% of the average yield of wheat in the same region. This observation is highly encouraging considering the fact that much greater research efforts were, and continue to be, put into wheat by the various categories of plant scientists, and considering the tremendously greater care and attention given to wheat by the farmers themselves. Consequently, there are good reasons to believe that, by improving the research and production programmes of barley, we may be able to bring up its yield to a level perhaps higher than that of wheat, thus achieving another green revolution as previously done for wheat by CIMMYT in Mexico and for rice by IRRI in the Philippines.

In order to do so, we need, first of all, to identify and/or develop stiff-strawed varieties of barley that can stand irrigation and greater amounts of fertilizers. When developed, such varieties can be more advantageously used in the irrigated sectors instead of the varieties now available, which are not fully responsive to these environmental conditions.

All the genetic factors associated with high yield seem to be available in the barley collections and/or populations now present. We do have the genes for short straw and straw-stiffness, high tillering, resistance to various diseases, photoperiod insensitivity and also for leaf erectness which seems to be correlated with higher phtosynthetic efficiency. We even have the genes for high protein and high lysine content of the proteins which, if properly recombined with other genes may result in the development of barley varieties possessing the high yield and higher nutritional quality characteristics. What we need, therefore, is more dynamic breeding programmes to bring all these desirable characters together in one or a small number of varieties which will then come to possess all the prerequisites for high yield under irrigation and high fertility conditions.

We should not forget, however, that barley is, predominantly, a rainfed cereal because a much greater proportion of this crop is grown without any irrigation and in areas where rainfall is generally low and subject, in addition, to great yearly fluctuations in amount and distribution. Consequently, the yields in such areas are low, highly unstable from one year to the next and may degenerate into a complete crop failure in years where rainfall falls below a certain threshold value.

The situation may seem helpless under these difficult conditions but there is still a great scope for improving the actual trends. It is true that the present scientific knowledge is not yet sufficient for operating a real breakthrough in yield in the rainfed areas- nevertheless, it is still possible to increase the present yield levels through selection of better adapted and more stable genotypes and through utilization of more adequate crop rotations and cultural practices compatible with efficient moisture-conservation measures.

However complex it may be, drought resistance is a reality. It may be correlated with deeper root system, greater earliness, more adapted phasic development, higher photosynthetic efficiency, lower evapotranspiration rate or a combination of all these and other factors. We may not yet fully understand all the criteria associated with drought resistance and yield stability, but a closer cooperation between plant physiologists, plant geneticists and plant breeders will undoubtedly result in the gradual building up of barley genotypes more adapted to drought conditions than the genotypes now commonly used. Here again we need sound breeding programmes and closer cooperation between scientists for tailoring a better barley crop for the rainfed areas. In such programmes, a great emphasis must be placed on identifying the proper

parents carrying one or more of the desirable characters associated with drought resistance and yield stability. After crossing, selection of the best genotypes during the segregating generations should be carried out in the proper environment to which they are ultimately destined.

Other Programmes

When better varieties are identified knowledge of the best and most efficient ways of exploiting their yield potential should be worked out in well-planned programs with clear production-oriented objectives. Since agriculture depends on the integration of a variety of disciplines the inter-disciplinary approach to the solution of practical problems is likely to give the best results in the shortest possible time and to avoid unnecessary duplications.

The increase of barley production in low-rainfall areas, for example, will not only depend on the identification of more adapted genotypes but also on the determination of the best tillage practices compatible with higher conservation, time, rate and depth of seeding and most suitable crop rotations and farming systems which will maximize yield in a given period of time.

In this context, it should be mentioned that the Australian dry farming system, which integrates cereals and animal husbandry through utilization of cereals/medics rotations, seems to have great promise in many countries of the Near East and North Africa. Some of the advantages of this system are: (1) abolition of the wasteful and commonly used cereal/fallow rotation, (2) gradual improvement of soil structure and fertility through utilization of leguminous crop species, (3) gradual increase in cereal yields and increase in the much needed livestock production, (4) reduction of soil erosion by wind and torrential rains, and (5) economy in the use of the more and more expensive nitrogenous fertilizers. This farming system has already proved its benefits in Algeria, Libya and Morocco and is now being introduced or contemplated in several other countries of the Region.

It must always be remembered that the farmer is the ultimate user of the new improved technologies. The experiments should then be planned with the idea of solving practical problems encountered at the farm level, taking into consideration the different agro-climatic and agro-ecological zones. As much as possible, the experiments should be carried out in the area where their results will ultimately find application, and their benefits demonstrated to the farmer in clear and simple ways. These demonstrations are the primary responsibility of the Extension Service personnel but they should also closely involve the breeders, agronomists, pathologists and other plant or soil scientists as well.

All these varied, but inter-related, activities will not be properly carried out in the absence of an adequate scientific and technical cadre provided with the necessary facilities. Most , if not all, national programs in the Region suffer a great shortage of well-trained and experienced research scientists at all levels. Much more training is needed in the fields of plant breeding, plant physiology, plant pathology, seed certification, extension and also in research leadership for planning and implementing production-oriented research projects.

But the ultimate aim of increasing production will not be attained, if the new improved technology is not made available at a reasonable and affordable price, specially at the small farm level. It is, therefore, important that small farmers be grouped into cooperative farming societies and accorded the necessary credit facilities for full participation in the increase of barley production through selective mechanization and adoption of the package of improved practices It is also important to maintain a barley price high enough to encourage these small farmers to invest in these new improved technologies.

Contribution of the UNDP/FAO Regional Project

Training

Aware of the shortage of trained manpower and of the extreme importance of the human element in agricultural development, the UNDP/FAO Regional Project on the Improvement and Production of Field Food Crops in the Near East and North Africa has always given this consideration the highest priority and provided opportunities for training at all levels from project and non-project funds . The leading idea is to strengthen the national programs through increasing the supply and competence of technical personnel in the member countries of the Project. The total number of trained scientists under the various training programs and in different crops/disciplines will reach about 317 by the end of 1977.

One of the latest of these opportunities is a five-year project (1976-1981) generously financed by the Government of Saudi Arabia under FAO/NE Cooperative Program. According to this project 50 persons will receive a one-year training course on systems of farming in Australia (10 persons every year). The first course was started in 1976 and the second will be initiated in May 1977.

Supply of Plant Material

The Regional Project supplies also every year a large breeding and experimental material of barley and other field crops through cooperation with the research institutions of the member countries, other regional programs (ALAD of the Ford Foundation), international programs (CIMMYT, University of Nebraska, USDA) and research institutes of many developed countries. The results of these cooperative yield trials/nurseries are compiled by the respective agencies, analyzed and distributed to cooperators.

Provision of Seed of HYV's and Plot Equipment

In order to accelerate the large-scale testing, multiplication and release of identified high yielding varieties of field crops, the Regional Project is now in a position to supply the member countries in the Near East and North Africa, and at no cost to them, with substantial quantities of seed of these improved varieties. This five-year project (1976-80) has become possible through the generous financial support of the Government of Bahrain under FAO/NE Cooperative Program.

Similarly, in order to increase the efficiency of the experimental work, sets of plot machinery and plot seed drills were supplied to the member countries under FAO/NORAD project. This help is likely to be extended in the future.

Improvement of Nutritional Quality in Barley and Spring Wheat

A five-year research project (1974-79) on the improvement of nutritional quality in barley and spring wheat is now underway. This project whose costs amount to US$ 1.8 million is financed by SIDA and involves the twinning of the Swedish Seed Association, Svalof, Sweden, and research institutes from six selected countries (India, Pakistan, Iran, Turkey, Egypt and Ethiopia).

The main objective of this project is to identify high protein-high lysine lines of barley and spring wheat and to combine these characters with others, such as high yield and disease resistance, by the normal breeding procedure. In addition, two scientists from each country will receive 9-month training in breeding and biochemical techniques, and the cooperating countries will receive laboratory equipment for the determination of protein and lysine contents. This direct coupling of institutes from developed and developing countries will be highly beneficial to the latters and should be encouraged in the future.

Hunger and malnutrition are afflicting more and more people on our planet every day and these problems can only be solved through closer cooperation at the national regional and international levels.

Table 1. Area, production and average yield of wheat, barley and total cereals in countries of the Near East and North Africa, 1974

Country	WHEAT			BARLEY			TOTAL CEREALS		
	Area (1000 ha)	Production (1000 tons)	Yield (kg/ha)	Area (1000 ha)	Production (1000 tons)	Yield (kg/ha)	Area (1000ha)	Production (1000tons)	Yield (kg/ha)
Afghanistan	2600	3000	1154	350	400	1143	3660	4720	1285
Cyprus	104	100	962	99	115	1162	205	216	1054
Egypt	576	1984	3447	32	99	3061	1975	7908	4004
Iran	5000	4100	820	1281	826	645	6778	6348	937
Iraq	1633	1339	820	519	533	1027	2266	2175	960
Jordan	220	225	1023	60	35	583	282	261	928
Lebanon	50	60	1200	8	8	1000	61	72	1171
Libya	115	70	609	300	100	333	418	173	413
Pakistan	6113	7629	1248	205	140	682	9557	12315	1289
S. Arabia	130	175	1346	14	22	1571	419	556	1325
Somalia							430	325	756
Sudan	174	235	1348			1063	3410	2527	741
Syria	1537	1630	1061	697	655	940	2283	2335	1023
Turkey	8754	11422	1305	2531	3475	1373	12505	16220	1297
Yemen AR	60	71	1183	170	230	1353	1180	1105	936
Yemen DR	15	15	1000	1	4	2917	58	95	1643
Algeria	2000	850	425	600	450	750	2660	1346	506
Morocco	1997	1850	967	1998	2389	1316	4530	4849	1070
Tunisia	1100	810	810	340	300	882	1401	1137	812
Total	32178	35565	1105	9205	9781	1062	54078	64683	1196
% of total	59.5	55.0	92.4	17.0	15.1	88.8	100	100	100
% of wheat	100	100	100	28.6	27.5	96.1			

Source: Near East Statistical Directory, 1975.

Table 2. Relative importance of Barley in countries of the Near East and North Africa, 1974

Country	Area (1000 ha)	Area (% of total)	Production (1000 tons)	Production (% of total)	Yield (kg/ha)	Yield (% of mean)
Afghanistan	350	3.80	400	4.09	1143	107.62
Cyprus	99	1.08	115	1.18	1162	109.42
Egypt	32	0.35	99	1.01	3061	288.23
Iran	1281	13.92	826	8.44	645	60.73
Iraq	519	5.64	533	5.45	1027	96.70
Jordan	60	0.65	35	0.36	583	54.90
Lebanon	8	0.09	8	0.08	1000	94.16
Libya	300	3.26	100	1.02	333	31.35
Pakistan	205	2.23	140	1.43	683	64.22
S. Arabia	14	0.15	22	0.22	1571	147.93
Syria	697	7.57	655	6.70	940	88.51
Turkey	2531	27.50	3475	35.53	1373	129.28
Yemen AR	170	1.85	230	2.35	1353	127.40
Yemen DR	1	0.01	4	0.04	2917	274.67
Algeria	600	6.52	450	4.60	750	70.62
Morocco	1998	21.71	2389	24.42	1316	123.92
Tunisia	340	3.69	300	3.07	882	83.05
Total	9205	100.00	9781	100.00	1062	—

Table 3. Average yield of barley in the Near East and North African region in comparison to the world and other regional averages

Region/Country	Average Yield (Kg/ha)
World	1867
Africa	899
N. C. America	2165
S. America	1141
Asia	1342
Europe	3125
Oceania	1240
U. S. S. R	1672
China	1476
Far East Region	1266
Developed Region	2634
Developing Region	1059
Near East & North African Region	1062

ICARDA

THE INTERNATIONAL CENTER FOR AGRICULTURAL RESEARCH IN THE DRY AREAS

W.L.Pelton and O.L.Brough[1/]

The International Center for Agricultural Research in the Dry Areas (ICARDA), established in 1976, is the newest of the international agricultural research centers under the sponsorship of the Consultative Group for International Agricultural Research (CGIAR). ICARSA's mission is to help increase and stabilize food production and thereby improve the economic and social benefits of people in developing countries of the temperate zone having arid or semi-arid climates. The ecological zone falling within its mandate consists primarily of areas that receive 300 to 800 mm of precipitation during the winter months and where rainfed or dryland farming systems predominate. Much of North Africa and the Near East, including Syria, Iran, Afghanistan, Pakistan and parts of Turkey and India fall within this broad zone which embraces in excess of 250 million people. Throughout this region, agricultural productivity is generally low and food shortage is a recurrent problem as population is increasing at a rate in excess of 3 percent annually. Levels of living are generally below acceptable minima.

Under the terms of its mandate, ICARDA has five major objectives:

(a) To serve as an international center for research into the improvement of barley, lentils and broadbeans, and other such crops as may be designated by the Board of Trustees in consultation with the CGIAR;

(b) To serve as a regional center, in cooperation with other appropriate international agricultural research centers for research in other crops of major importance to the region, such as wheat and chickpeas;

(c) To conduct research into and develop, promote and demonstrate improved systems of cropping, farming and livestock husbandry;

1/ Assistant Directors General for Development and Administration, respectively.

(d) To collaborate with and foster cooperation and communication among other national, regional and international institutions in the adaptation, testing and demonstration of improved crops, farming and livestock systems; and

(e) To foster and support training in research and other activities carried out in furtherance of its objectives.

The Center will engage in all such activities as are conducive to the furtherance of its objectives, and, without limiting the generality of the foregoing, such activities will include:

(a) The collection, evaluation, maintenance, manipulation, distribution and exchange of basic germ plasm and of improved plant and animal materials for use in national, regional and international agricultural research, development and production programs;

(b) The identification and evaluation of improved farming systems, including livestock husbandry and the development of related systems of pasture improvement and management, especially through site-specific cooperative programs;

(c) The assembly and evaluation of information relative to the physical, biological and socio-economic problems which impose constraints on the wide-spread adoption of improved systems of cropping, farming and livestock husbandry;

(d) The study and evaluation of factors pertaining to preharvest and post-harvest protection of the crops for which the Center is responsible;

(e) The training of scientists, technicians and other persons to improve the research and production capacities within the region; and

(f) The demonstration, publication and dissemination of research results generally.

ICARDA expects to work in three primary locations. Principal research stations will be developed in Syria and Iran to conduct research on farming systems and crop improvement.

ICARDA's mandate calls for a plant breeding research station in the Bekaa Valley of Lebanon. The need for such a station has not yet been firmly established and, because of the civil strife in Lebanon, the Board of Trustees has deferred the final decision on this matter until ICARDA's program of research has been further defined and developed.

The overall research program of ICARDA will be framed within a farming systems context that will serve to integrate four major research thrusts. These are:

a) Farming Systems Research;
b) Cereal Improvement;
c) Food Legume Improvement; and
d) Forage Crop Improvement.

Farming Systems Research Program

The farming systems research program will provide the scientific basis for a wide range of strategies designed to make effective use of the human, environmental and other resources of the region. The program can be visualized as three sub-programs:

(a) Environmental Systems Research
This research will characterize the key environmental parameters that control the acceptance and adaptation of crops and pastures in the region. This will lead to the development of realistic simulation models to predict the availability of moisture and the growth of crops throughout the region, to evaluate alternative cropping practices and to assist the plant breeders in defining more realistic breeding objectives for the important crops to be grown in the region.

(b) Resource Management Research
This sub-program will have the responsibility of developing and integrating new technology with established components of the various farming systems now practiced in the region. A major objective will be to optimize the utilization of physical and biological resources in the region and to develop "packages" of technological practices for farmers of various means.

(c) Socio-Economic Research

This sub-program will complement the work of the Environmental System and Resource Management groups by identifying and evaluating the constraints inherent in existing farming systems which limit potential productivity throughout the region. Such research will be concerned with the consequences of introducing new technology and the economic implications of recommending changes in farming practices. New technology will be thoroughly evaluated to ensure that it is economically viable, technically feasible and sociologically acceptable.

In developing basic farming patterns that can be recommended for reasonably wide areas, the inter-disciplinary team will focus its attent on the need for effective and efficient water management - the key to successful dryland agriculture.

Cereal Improvement Program

Wheat and barley are sown on approximately 40 percent of the arable land in the region as winter cereals. Usually, these cereals are grown under rainfed conditions with one crop being taken each year because the distribution of annual precipitation is restricted to the winter months. Super-imposed on the limited precipitation regime are wide extremes in the duration of crop growth, temperature and soil type. All of these factors will influence the research requirements of ICARDA's Winter Cereal Program.

The cereal improvement program will be concerned to varying degrees with barley, durum wheat, bread wheat and triticale. This program too, will be organized around an inter-disciplinary team approach involving research activity in breeding, pathology, physiology, agronomy, seed and quality technology, weed control and plant nutrition. The main objectives of the program are to improve and stabilize the production of barley and wheat which are the most important cereal crop components of the farming systems in the region. In addition, the potential of triticale will be explored with an aim to improve its adaptation to a wider range of environments.

In an effort to broaden the germ plasm base of cereals and to preserve worthy local cultivars, national programs will be encouraged to make collections and to make available existing genetic materials for regional evaluation and distribution. The program will also launch its own germ plasm collection missions from time to time.

Food Legume Improvement Program

Food legumes are an important staple food for many of the poorer people of the region because they frequently contribute a significant portion of dietary protein. They are also important as cash crops and are valuable components in many crop rotations throughout the region.

ICARDA's research program will focus on the improvement of cultivars and production practices of lentils and broadbeans and through cooperation with other international centers on chickpeas and perhaps dry beans. It is hoped that a small program on dry peas may be initiated at a future date. Again, an inter-disciplinary approach will be used to attack the multitude of problems that now limit the potential and stability of food legume production in the region of ICARDA's mandate.

Genetic improvement research on the food legume crops will concentrate on disease and pest resistance and stress tolerance. In addition, certain crop-specific characteristics will be considered in the breeding program such as the suitability for mechanical harvesting of lentils and improved autofertility of broadbeans.

A wide range of agronomic studies will aim at identifying optimum planting dates, seeding rates and fertility requirements.

The germ plasm collection of both lentils and broadbeans will be expanded by field collection and by exchange with other breeders.

Forage Crop Improvement Program

In the short term, this program will focus on the development of successful forage legumes to be used in conjunction with the cereal rotation as ley pastures for sheep. The purpose of these annual and perennial legumes will be to enhance the fertility level (especially nitrogen) for following cereal crops and to provide valuable quality forage for sheep as part of an integrated farming system. Ultimately, it may be desirable to work on a wider range of fodder crops including grasses, which may play an important role in the nutrition of sheep.

ICARDA's present germ plasm collection of forage legumes is limited and field collection missions to broaden the current base are of high priority. Initially, the breeding program will be directed toward the identification and improvement of annual medics, vetches, sainfoins

and lucerns. Breeding objectives for annual medics will be to incorporate cold tolerance into the established varieties which are adapted in the region.

The forage crop improvement program will incorporate a strong agronomic input to evaluate the adaptability, herbage yield and seed production of varieties under development. The effects of grazing and mowing on seed set, seed dormancy and hard-seededness will be studied.

Many lines of triticale, barley, sudangrass and forage millet will be screened for forage production and evaluated for their performance under dryland conditions. This work will be in support of ICARDA's concern with the problems of identifying suitable crops for a range of productive farming systems. Establishment and growth from residual winter moisture will be a prime consideration in evaluating these crops for forage production.

Training and Conferences

Training will have a high priority at ICARDA. This program will have two primary goals:

(a) To assist in the transfer of knowledge generated by the research programs to those who need it and can use it; and

(b) To respond to the expressed need for training in research skills and to share the knowledge and expertise of the staff with those who need it to improve food production in their home countries.

Although training programs have not yet been defined, it is expected that a variety of course types will be offered to meet the needs of agricultural personnel in the region. Practical, in-service training in research techniques will be emphasized and conducted over a cropping season. Recipients of this type of training will be called upon to supervise the ICARDA based nurseries accepted by their home countries.

Training programs will also be offered to personnel from national programs who train or supervise extension workers. These courses will familiarize training personnel with improved technological practices and assist them in designing effective demonstration and extension programs in their home countries. The objective of this type of training will be to develop the technical, economic, scientific, farming and communication competencies of extension personnel from the region.

Plans are being formulated to accommodate visiting scientists and post-doctoral fellows. When the training program is fully developed it may be possible to provide limited degree-related training through close working relationships with universities in the region.

ICARDA intends to draw heavily on the support and assistance of the international scientific community through the sponsorship of well-conceived workshops, conferences and seminars. This vital communication channel will be expanded and strengthened as ICARDA developes.

International Cooperation and Regional Research Activity

ICARDA hopes to develop close working relationships with a number of other international centers. Such cooperative programs will avoid unnecessary duplicity of research effort, and will provide comprehensive studies of site-specific problems.

Regional research programs will be considered as among the most important aspects of ICARDA's mission. These programs will be closely linked to ICARDA's training activities which, in turn, will provide leadership for agricultural research and extension throughout the region. ICARDA intends to pursue new regional research relationships as rapidly as staff and resources for ensuring successful projects become available. Successful cooperative programs that go beyond offsite testing require a concentrated effort for a sufficiently long period to solve problems and to strengthen national research and development capabilities in particular crop and production systems.

ICARDA Today

Despite the fact that ICARDA was not formally established until the first meeting of its Board of Trustees in August 1976, its crop improvement research programs have been upper-most in the minds of the Ford Foundation scientists attached to the Arid Lands Agricultural Development (ALAD) Program in Lebanon for several years.

As a result of the civil strife in Lebanon, the ALAD scientists duplicated all nurseries in Egypt to ensure that this extensive program would not be interrupted and efforts continued in the areas of research and development of cereal, food legume and forage crops. Some nurseries were also planted in Syria and Lebanon and off-season nurseries were established in Jordan, Ethiopia, and Kenya. The management and research staff of ICARDA take this opportunity to extend appreciation to the government and university officials of each of the above countries for

providing the land and facilities necessary to continue this program. As a result of this cooperation, our scientists distributed more than 200 sets of cereal and legume nurseries to more than 50 countries during 1976.

On January 1, 1977, ICARDA absorbed the relevant activities and staff of the former ALAD program and, at present, has nurseries of cereals, food legumes and forage crops planted on approximately 70 hectares in Egypt, Syria and Lebanon.

ICARDA has a ratified agreement with the Government of Syria and has selected a 1000-hectare research site 25 km. South of Aleppo. It is expected that land acquisition will be completed by mid-summer of 1977.

ICARDA's agreement with the Government of Iran is now before parliament and ratification is expected by mid-May. In the meantime, a team of consultants is in Iran on a mission to identify potential sites for ICARDA's principal station in that country.

ICARDA's staff now totals 14 International Administrative, Research and Support personnel, and 70 locally appointed research and support staff.

Despite its very recent beginnings, ICARDA has an active staff, a viable organization and a useful and expanding research program underway.

THE INTERNATIONAL MAIZE & WHEAT IMPROVEMENT CENTRE (CIMMYT)

By

Glenn G. Anderson*

To start with I would like to briefly review the events leading up to CIMMYT's involvement in barley breeding work. Originally barley breeding in Mexico was undertaken by the joint Mexico-Rockefeller Foundation agricultural development program. When this joint project was brought to a close, the entire program, including the barley breeding element, was taken over by the Mexican government. In the years that followed some of the remaining Rockefeller Foundation personnel cooperated with several other Latin American countries to extend the old program into a small nursery program throughout Latin America.

At the same time the Rockefeller Foundation through the FAO Middle East Regional office initiated a joint training program for young scientists from the Middle Eastern countries. Seeing the work being carried out in Latin America, and interested in the international aspects of testing they became involved with this nursery program which thus put it on an international footing.

In 1966 CIMMYT was officially formed and international programs were initiated in wheat (bread and durum) and maize. Work on triticale was started later, expanded in 1967-68 and elevated to full program status in 1971.

Since 1966 there has been considerable staff expansion and the number of people working internationally both inside and outside Mexico has gradually but substantially increased.

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It has been known for a long time that wheat was ill-adapted to areas outside the high rainfall belts of the world, and at higher altitudes with a short growing season. For this reason it was decided to initiate a barley breeding program at CIMMYT. This program was primarily directed towards developing barley varieties for food and feed.

Because most of the earlier efforts had been geared towards breeding malting barleys due to very favourable systems of price premiums and because the requirements for successful malting varieties are so different to those for feed varieties (i.e. tight hulls and low protein content) work had to start from scratch.

The program was designed around the hulless type of barley to eliminate the necessity for dehulling. This was mainly because both the dehulling methods (i.e. pearling and soaking) result in losses in food value. A further consideration being that hulless barleys are consumed by a considerable section of the world population.

By the time the barley breeding program was initiated CIMMYT had already built a well developed international program and nursery system around its main crops. This structure has thus been very profitably used to serve the barley research efforts. The program has advanced considerably since its inception in 1971-72 when much germplasm was supplied from sources all over the world. This material has been integrated and bulked by growing two crops per year, one at Obregon and the other at high altitudes near Mexico City. Thus we have been able to steadily increase our nursery material from 41 trials distributed in 1973, to 73 in 1974 and 165 in 1976. This increase is expected to continue as more material becomes available. Four types of nursery are currently being distributed:-

F_2's from various crosses

International Barley Observation Nurseries (IBON)

Crossing Blocks

Elite Barley Yield Trial (EBYT)

CIMMYT, with its well equipped laboratories already studying the development of high lysine maize varieties was ideally placed to work on the raising of the nutritional value of barley through the development of high proline varieties.

We have one major problem in the case of naked (hulless) types of barley where the embryo projects past the end of the kernel. This has resulted in considerable embryo damage during mechanical threshing and a consequent lowering of the germination capacity of the seed. Such damage may not be significant when threshing is not mechanical but is a considerable set back in more mechanized production systems. High proline varieties with shrunken endosperm are accentuating this problem. However the linkage is not infallible and we are now producing varieties with high protein content and good kernels (e.g. one variety has 12% protein, 4.8% lysine and a well developed kernel). So this shrinkage problem does not seem insoluble.

With regard to grain yield; we have identified lines which yield up to 7.8 tons per hectare in Mexico under irrigated conditions. Of more interest, however, is a line derived from Early Russian which gave yields of 3.8 tons per hectare on the basis of only one irrigation applied to give good germination. This particular line has also shown that a short growing season (35 days to flowering) can effectively be combined with a reasonable yield level.

In all, I feel the barley program at CIMMYT is moving ahead well. We are incorporating disease resistance, most materials have good straw strength and much of the material is early maturing. Earliness is especially important for the more marginal areas such as the arid zones and highland mountainous regions and we are now concentrating on developing varieties more suited to these particularly important areas of the world.

MONTANA STATE UNIVERSITY / AID BARLEY RESEARCH PROGRAM

Lark P.Carter*

Barley improvement research has been conducted at Montana State University for over 80 years. One of the first research projects of the newly established Agricultural College of the State of Montana, now Montana State University, included barley selection and variety evaluations. Barley improvement research efforts have continued on a regular basis by the Montana Agricultural Experiment Station since its establishment in 1893.

Montana State University is a Land Grant University located in the northwestern part of the United States at Bozeman, Montana, about 125 kilometers from Yellowstone National Park. It lies in the fertile Gallatin Valley, surrounded by mountains of the Rocky Mountain Range. The elevation at Bozeman is about 1500 meters. The State of Montana includes about 37,200,00 hectares of land. It is sparcely populated with about 725,000 people. The topography varies greatly with mountains ranging to 3900 meters. Much of the land is covered by forest and native range. Rainfall varies greatly also but much of the cultivated crop land of the state receives from 28 to 35 cms annually.

Homesteaders began to settle in eastern and northern Montana at the turn of the century and the attention of the Experiment Station was focused on the potentialities of dryland cultivation. One of the early bulletins on this subject "Dry Farming in Montana" was published in 1907. This was followed in 1908 by another bulletin "Dryland Practices in Montana", which summarized studies made at 6 outlying research stations, and stressed moisture conservation, summer fallow and other cultural practices for increased crop production in this semiarid region.

Barley is uniquely well adapted to Montana's environment, especially the vast rainfed semi-arid regions of the state. It usually outyields other spring sown cereals in Montana; and does particularly well under poor soil conditions, with low rainfall and under unfavorable climatic conditions. There are from 700,000 to 800,000 hectares of barley

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* Associate Dean of Agriculture, Assistant Director Montana Agricultural Experiment Station and Co-principle investigator of the USAID supported research project "Improvement of the Nutritional Quality and Productivity of Barley for Semi-Arid Regions". Montana State University, Bozeman, Montana 59715.

grown annually in Montana. Montana usually ranks second in area seeded to barley and either second or third in total production of barley in the United States. The number of hectares of barley in Montana is expected to rise sharply this year in response to anticipated drought conditions. The farmers know that barley often does better than other crops under adverse climatic conditions.

In 1971 a research project proposal entitled "Improvement of the Nutritive Quality and Productivity of Barley for Semi-arid Regions of the World" was developed. It was finally submitted to AID for evaluation in 1972. After revision, rewriting and waiting for congressional action related to funding the Agency for International Development, the project was finally approved and signed in May of 1974.

The overall objectives of this research effort can be summarized as follows:

1. To increase the nutritive value of barleys consumed by people throughout the world, particularly in less developed countries.

2. To increase the yield of barley grown in semi-arid regions of the world, particularly in less developed countries.

3. To decrease losses caused by barley diseases, particularly in less developed countries.

To achieve these objectives we proposed to work in cooperation with appropriate International Centers to survey representative countries to evaluate present barley cultivars for general agronomic characteristics, utilization patterns, and the prevalence of diseases and other pests.

It was also proposed that workshops and seminars would be developed and organized in cooperation with appropriate International Centers to report on progress of the project and exchange information and experiences related to the barley improvement effort.

Finally it was also proposed that workshops and seminars would be developed and organized in cooperation with appropriate International Centers to report on progress of the project and exchange information and experiences related to the barley improvement effort.

The AID funded project compliments the barley research program that has been a continuing one conducted by the Montana Agricultural Experiment Station.

The following Montana State University professional staff are devoting all or part of their efforts towards the objectives of this project:

Dr. Harold Bockelman, Post Doctorate
(Plant Pathology)

Dr. Jarvis H. Brown, Associate Professor of Agronomy
(Crop Physiology)

Dr. Thomas W. Carroll, Professor of Plant Pathology
(Virology and electron microscopy)

Dr. Lark P. Carter, Associate Dean of Agriculture
(Co-project leader, Professor of Agronomy)

Dr. A.M. El-Negoumy, Professor of Agricultural Biochemistry
(Protein chemistry)

Professor Robert F. Eslick, Professor of Agronomy
(Co-Project leader, genetics and plant breeding)

Dr. A.H. Ferguson, Professor of Soil
(Soil Physics, water use efficiency)

Dr. Eugene A. Hockett, Research Agronomise, USDA, ARS.
(Genetics and plant breeding)

Dr. Charles F. McGuire, Associate Professor of Agronomy
(Cereal chemistry)

Dr. B.R. Moss, Associate Professor of Animal Science.
(Animal Nutrition)

Dr. C.W. Newman, Professor of Animal Science
(Animal Nutrition)

Dr. Eugene L. Sharp, Professor of Plant Pathology
(Plant pathology, Department Head)

Dr. Loren E. Wiesner, Associate Professor of Agronomy
(Seed physiology)

The overall barley research program at Montana State University is an integrated, interdepartmental effort that brings together many disciplines and areas of expertise in an attempt to solve complex problems related to improvement of barley for semi-arid regions of the world. To reach our objectives, the research results, the barley populations developed and the improved practices and procedures developed not only by the research effort at Montana State University but also by barley researchers everywhere must be disseminated broadly and put into use. These are attainable goals and by working together they can be accomplished.

THE INTERNATIONAL WINTER WHEAT PERFORMANCE NURSERY (IWWPN)

K.D. Wilhelmi and V.A. Johnson*

Establishment

The International Winter Wheat Performance Nursery (IWWPN) was organized in 1968 by the Agricultural Research Service, U.S. Department of Agriculture, and the Nebraska Agricultural Experiment Station. In conjunction with a contract initiated in 1966 to improve the nutritional quality of wheat via breeding, the Agency for International Development, U.S. Department of State has been providing funds for this project.

Objectives

The objectives of this nursery are as follows:

1. To obtain information on the adaptation and performance of winter wheat varieties over a wide range of environments.

2. To test the stability of genes for improved protein and/or lysine content of the grain.

3. To provide breeders and other cooperators with an effective vehicle for identification and exchange of useful germplasm.

Operation

The IWWPN consists of 30 cultivars with four replications. Four check varieties are included each year for the purpose of measuring winter severity, protein level (high vs. low) and yield performance. Check varieties include Lerma Rojo 64, (Mexico) Atlas 66 and Blueboy (NC, U.S.A.) and Bezostaya 1 (USSR).

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* Assistant Professor, Wheat Breeding, University of Nebraska, Lincoln; Research Agronomist, Agricultural Research Service, U.S. Department of Agriculture, and Professor, University of Nebraska, Lincoln.

Data are collected on grain yield, test weight, maturity, plant height, lodging, shattering, winter survival, frost damage, 1000-kernel weight, protein, and various diseases. All miscellaneous data reported by cooperators also are analyzed and reported. All data are processed at the University of Nebraska computer network with publication of a Preliminary Report of results after each harvest on January 1. A final report of each IWWPN is published approximately two years following its harvest. This delay results primarily from sites in the Southern Hemisphere which are harvested six months later than those in the Northern Hemisphere. Also, processing of the large number of grain protein samples returned by cooperators is a lengthy process.

The growth of the IWWPN since 1969 in the number of locations and countries growing the nursery is shown in Table 1. The number of locations growing the nursery increased from 23 in 1969 to 65 in 1977. Over the same period of time the number of countries in which nurseries are grown has increased from 16 to 37. Most of the test sites are located in the Northern Hemisphere. In 1977, for example, 58 of the test sites are in the Northern and only seven in the Southern Hemisphere. Nursery sites now are located in all important winter wheat producing countries of the world except the People's Republic of China and Greece.

Varieties tested in the IWWPN have originated from 24 different countries (Table 2). A total of 110 varieties will have been evaluated for at least one or more years with the completion of the 9th IWWPN in 1977. The United States, Russia, Romania, Yugoslavia, Italy, and Hungary have provided a large number of the varieties tested to data.

Varieties in the IWWPN are tested for a two-year period. Candidate varieties for possible IWWPN testing are accepted from both private and public breeders who may not themselves be cooperators. Desired traits of candidate varieties are listed in Table 3. Seed of candidate varieties must be received at Lincoln, Nebraska by September 1 for increase under plant quarantine at Yuma, Arizona (Table 4). The seed increase together with required early distribution of nursery seed results in a 2-year delay in the entry of a variety in the nursery from the time seed is received.

Table 1. SUMMARY OF IWWPN SITES

Nursery Number	Year	Number of Locations	Number of Countries
1	1969	23	16
2	1970	38	25
3	1971	38	25
4	1972	44	27
5	1973	50	31
6	1974	48	30
7	1975	59	36
8	1976	64	39
9	1977	65	37
10	1978	66	37

Table 2. SUMMARY BY COUNTRY OF THE NUMBER OF WINTER WHEAT VARIETIES TESTED IN THE IWWPN, 1969-1977.

Country	Number of Varieties Tested	Country	Number of Varieties Tested
Argentina	1	Romania	7
Australia	1	Sweden	2
Austria	2	Switzerland	1
Bulgaria	3	Turkey	2
Canada	1	USA	31
Chile	4	USSR	9
England	3	West Germany	5
Finland	2	Yugoslavia	11
France	2		
Hungary	6		
Iran	1		
Italy	7		
Japan	2		
Korea	1		
Mexico	2		
Netherlands	4		
Totals: 24 Countries		110 Varieties	

Table 3. IWWPN - DESIRED TRAITS IN CANDIDATE VARIETIES

1. High yield potential
2. Acceptable level of winter-hardiness
3. Desirable combination of plant height and straw strength
4. Reasonable levels of disease and insect resistance
5. Desirable protein quality and quantity
6. Germplasm with potential value in breeding programs

Table 4. IWWPN - SUBMISSION OF CANDIDATE VARIETIES

1. Clean, pure seed - 1kg
2. Variety name or number
3. Pedigree is desirable
4. Variety description - morphological and agronomic traits
5. Seed must be received at Lincoln,Nebraska by September 1 for increase under quarantine at Yuma, Arizona.

Table 5.

HIGHEST YIELDING CULTIVARS IDENTIFIED
IN THE IWWPN NETWORK, 1969-1976*

Cultivar	Source
Bezostaya 1	USSR
Blueboy	USA,NC
San Pastore	Italy
Sturdy	USA, TX
Sava	Yugoslavia
Dacia	Romania
Probstdorfer Extrem	Austria
Centurk	USA, NE
Zlatna Dolina	Yugoslavia
Kavkaz	USSR
Aurora	USSR
Burgas 2	USSR
Maris Nimrod	England
Talent	France
GKF-2	Hungary
Priboy	USSR
WWP 7147	Austria
Martonvasar 2	Hungary
F26-70	Romania

* Cultivars yielding more than 40 q/ha and ranking among the highest five in yield performance during one or more years over all locations.

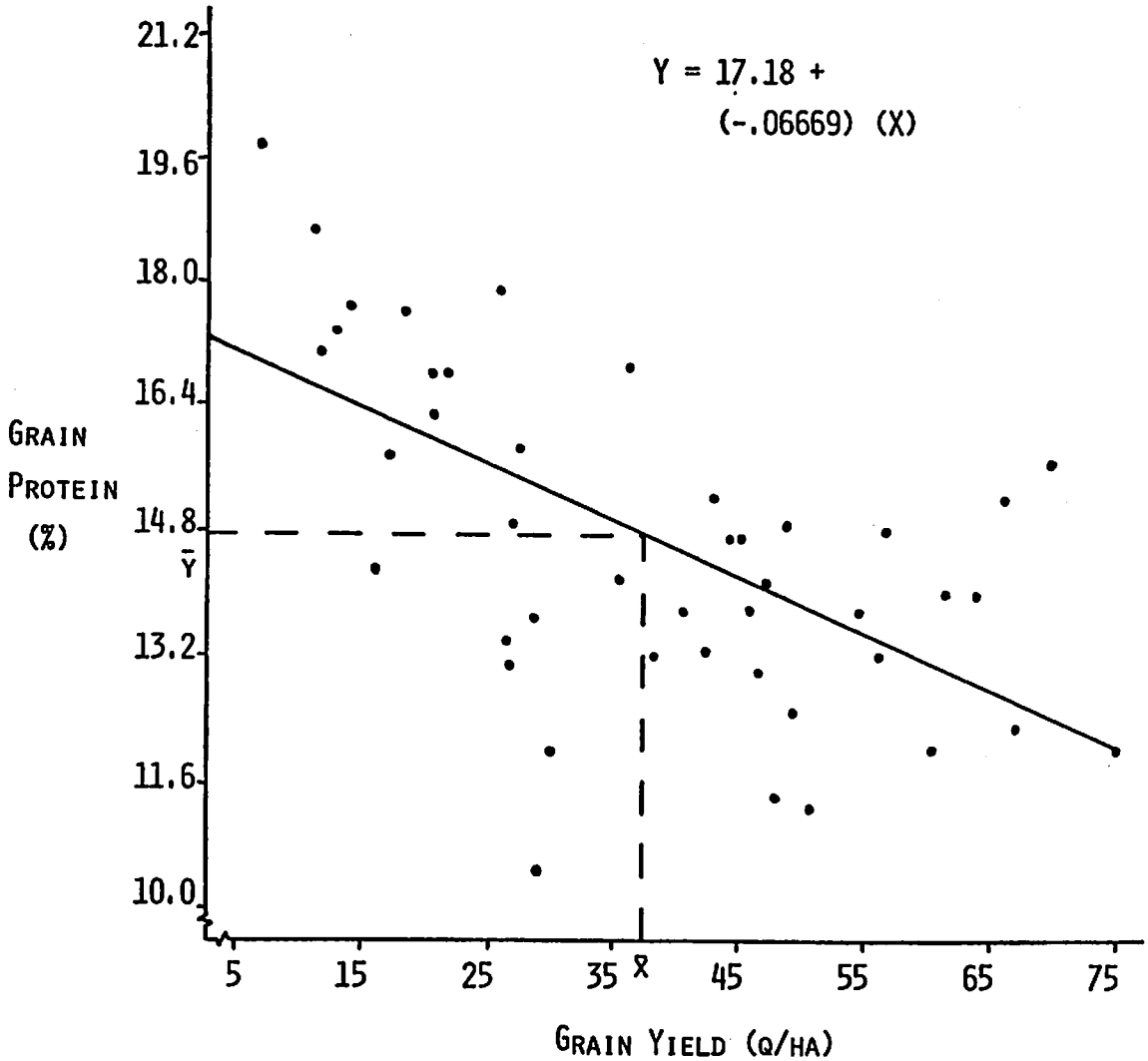

FIGURE 1. LINEAR REGRESSION OF GRAIN PROTEIN ON GRAIN YIELD OVER 43 LOCATIONS USING NURSERY MEAN YIELDS FROM THE IWWPN IN 1974.

Table 6. YIELD AND PROTEIN CHARACTERIZATION OF SELECTED IWWPN CULTIVARS GROWN IN 1973

Cultivar	Yield* q/ha	Yield* Rank	Protein* %	Protein* Rank
Group I:				
Sava	45.0	(1)	13.5	(23)
Centurk	42.2	(2)	14.0	(19)
Blueboy	40.8	(5)	12.4	(30)
Lancota	38.2	(12)	15.5	(3)
Moldova	38.3	(11)	15.2	(4)
Dacia	40.7	(7)	14.9	(7)
Probstdorfer Extrem	40.4	(8)	14.7	(6)
Group II:				
Atlas 66	34.7	(21)	16.7	(1)
CI 15074	34.1	(22)	15.7	(2)
Carifen 12	33.7	(23)	12.9	(29)
Hokuei	35.1	(19)	13.3	(27)

* Yield and protein means based on 43 and 31 locations, respectively.

Table 7. YIELD AND PROTEIN CHARACTERIZATION OF SELECTED IWWPN CULTIVARS GROWN IN 1974

Cultivar	Yield* q/ha	Yield* Rank	Protein* %	Protein* Rank
Group I:				
Blueboy	40.0	(6)	12.9	(30)
Maris Nimrod	40.7	(3)	13.4	(28)
Caribo	39.9	(7)	13.6	(26)
Kavkaz	42.0	(1)	15.0	(10)
Burgas 2	40.3	(4)	15.1	(8)
Aurora	41.9	(2)	14.9	(11)
Group II:				
Kirac 66	28.8	(30)	15.2	(7)
Lancota	33.9	(25)	16.0	(2)
Atlas 66	30.8	(28)	16.9	(1)
NS 732	31.1	(27)	13.8	(22)
Diplomat	32.9	(26)	14.4	(14)

* Yield and protein means based on 45 and 35 locations, respectively.

Table 8. COMPARISON OF PLANT HEIGHT AND GRAIN YIELD FOR IWWPN CULTIVARS IN 1972

Height Group and Cultivar	Plant Height (cm)	Grain Yield (q/ha)	Yield Rank*
Number of sites:	29	36	36
Shortest:			
Victor I	79	28.1	28
Zlatna Dolina	81	40.8	5
Rousalka	82	38.8	10
Sava	85	42.3	2
Intermediate:			
Marimp 3	94	32.3	20
Maris Nimrod	98	40.5	7
Bezostaya 1	99	43.4	1
Tallest:			
Blueboy	107	40.7	6
Centurk	107	40.4	8
Dacia	109	41.9	3
Probstdorfer Extrem	111	41.6	4
Starke	114	28.3	27
Jyva	115	26.9	29

* Based on mean yields of 29 cultivars.

Table 9. ASSOCIATION OF PLANT HEIGHT, LODGING AND GRAIN YIELD AMONG CULTIVARS GROWN IN THE IWWPN IN 1973

Cultivar	Height*		Lodging*		Yield*	
	cm	Rank	%	Rank	q/ha	Rank
Atlas 66	118	(30)	47	(28)	35	(21)
Probstdorfer Extrem	117	(29)	38	(24)	40	(8)
Kirac 66	114	(28)	63	(30)	30	(26)
CI 15074	109	(27)	38	(25)	34	(22)
Rousalka	80	(4)	7.8	(4)	43	(3)
Victor I	79	(3)	7.7	(6)	35	(20)
Zlatna Dolina	77	(2)	7.6	(5)	42	(4)
Carifen 12	77	(1)	5.8	(3)	34	(23)

* Means based on 33, 28, and 43 locations, respectively.

Nursery Results

Varieties exhibiting high grain yield potential have originated from several different countries (Table 5). Varieties yielding in excess of 40 q/ha over all IWWPN locations include one or more from Austria, England, France, Hungary, Italy, Romania, United States, Russia, and Yugoslavia. Several varieties in recent nurseries have out-yielded Bezostaya 1 across all environments. Bezostaya 1 has previously been recognized for its yield performance and stability in Europe and the Middle East.

Protein level in wheat grain is determined largely by production environment and the availability of soil nitrogen. Genes for grain protein can only be expected to increase the protein content of inherently high varieties over comparably productive ordinary varieties when both are grown in the same environment. Production environments vary tremendously between years and locations. For example, in the 1974 IWWPN, nursery mean yields ranged from 7.1 q/ha at Stillwater, Oklahoma to 69.9 q/ha at Svalof, Sweden (Figure 1). Nursery mean protein percentages also showed a large range and varied from 10.5% at Davis, California to 19.8% at Stillwater, Oklahoma.

The relationship between yield level and protein content is inconsistent among nursery sites. Varieties have been identified that possess both ordinary and high levels of grain protein within various yield groups. There has been excellent expression of genetic potential for high grain protein in Atlas 66 and its derived cultivars, CI 15074 and Lancota (Tables 6, 7) [2], [3]. Two varieties emanating from the U.S.S.R., Kavkaz and Aurora, and Burgas 2 from Bulgaria have exhibited elevated grain protein levels in combination with excellent yield potential.

There is a definite association between plant height and lodging with the taller cultivars tending to lodge more under high grain yield environments. However, high grain yields have been obtained from short, intermediate, and tall varieties (Table 8) [1]. The varieties Dacia from Romania and Probstdorfer Extrem from Austria are tall varieties but yield well. In the 1973 IWWPN neither the four tallest nor the four shortest cultivars were the highest in average grain yield (Table 9) [2]. A similar situation was found for the plant height-grain yield relationship in 1974 (Table 10) [3]. High yielding varieties were obtained in each plant height grouping in 1974 (Table 11).

Table 10. IWWPN CULTIVAR ASSOCIATION OF PLANT HEIGHT, LODGING AND GRAIN YIELD AMONG CULTIVARS GROWN IN THE IWWPN IN 1974

Cultivar	Height*		Lodging*		Yield*	
	cm	Rank	%	Rank	q/ha	Rank
Atlas 66	109	(30)	45	(28)	31	(28)
Kirac 66	106	(29)	58	(29)	29	(30)
Lancota	103	(28)	42	(27)	34	(25)
Bolal	102	(27)	59	(30)	35	(21)
Zlatna Dolina	74	(4)	2	(4)	40	(8)
Sanja	71	(3)	3	(6)	38	(13)
Dwarf Bezostaya	65	(2)	1	(1)	38	(14)
NS 732	59	(1)	5	(10)	31	(27)

* Based on 37,25, and 45 locations, respectively.

Table 11. COMPARISON OF PLANT HEIGHT AND GRAIN YIELD FOR IWWPN CULTIVARS IN 1974

Height Group and Cultivar	Plant Height (cm)	Grain Yield (q/ha)	Yield Rank
Number of sites:	37	45	45
Shortest:			
NS 732	59	31.1	27
Dwarf Bezostaya	65	38.3	14
Sanja	71	38.4	13
Zlatna Dolina	74	39.6	8
Burgas 2	81	40.3	4
Intermediate:			
Marimp 3	86	34.7	22
Maris Nimrod	89	40.7	3
Bezostaya 1	92	40.2	5
Aurora	93	41.9	2
Blueboy	96	40.0	6
Tallest:			
Kavkaz	98	42.1	1
Dacia	100	38.6	12
Kirac 66	106	28.8	30
Atlas 66	109	30.8	28

There is a positive relationship between test weight, 1000-kernel weight and grain yield. This has been shown by highly significant correlation coefficients 'r' among these traits in several IWWPN's. Some varieties exhibit both high test weight and high 1000-kernel weight, but other varieties are high in one trait and low in the other (Tables 12, 13). Varieties such as Bezostaya 1, Aurora, Martonvasar 2, and Priboy support the first case. Maris Templar and Lilifen are high in 1000-kernel weight but low in test weight. The variety Bordenave Puan Sag is low in 1000-kernel weight but is high in test weight.

High Protein-High Lysine (HP-HL) Observation Nursery

In 1975 the first HP-HL observation nursery was distributed to 25 locations in 20 countries. The nursery consisted of 280, unreplicated entries ranging in growth habit from spring to winter types. In 1976 and 1977 two nurseries were distributed, one representing the winter type growth habit and the other spring (Table 14).

Wheat seed samples from harvested plots from many test sites of the 1975 HP-HL have been returned to our quality laboratory at Lincoln, Nebraska for protein and lysine analyses. Mean protein and lysine percentages exhibited a wide range when computed over 15 experimental locations. Progeny of crosses involving Nap Hal/Atlas 66 were consistently high in grain protein, the highest being 22.4% (Table 15). Lines evolving from the cross CI 13449/Centurk generally showed the lowest grain protein percentages.

Lines exhibiting elevated lysine as a percentage of protein came from the cross of CI 13449/Nap Hal (Table 16). This cross has produced several highly productive lines with grain lysine levels higher than either parent variety.

Several lines were identified in the first HP-HL nursery that possess elevated levels of both grain protein and lysine as a percent of protein (Table 17). It is noteworthy that these lines possessed protein values higher than the check varieties except Atlas 66, while maintaining a lysine/ protein percentage higher than 3.01%.

Table 12. VARIETIES IDENTIFIED IN THE IWWPN POSSESSING SUPERIOR TEST WEIGHT*

Variety	Country	kg/hl
WWP 7147	Austria	81.4
Parker	USA, KS	81.0
Odesskaya 51	USSR	80.9
Bordenave Puan Sag	Argentina	80.6
Priboy	USSR	80.4
Triumph 64	USA,OK	80.4
NB 68513	USA,NE	80.0
Shawnee	USA,KS	80.0
Bezostaya	USSR	79.9
Lancota	USA,NE	79.9
Probstdorfer Extrem	Austria	79.9
Aurora	USSR	78.3
Dunav-1	Yugoslavia	77.8
Martonvasar 2	Hungary	77.8
Favorit	Romania	77.6

* Means over years in which the variety ranked among the highest five in test weight.

Table 13. VARIETIES IDENTIFIED IN THE IWWPN POSSESSING SUPERIOR 1000-KERNEL WEIGHT*

Variety	Country	Grams
Aurora	USSR	42.6
Martonvasar 2	Hungary	42.4
Martonvasar 3	Hungary	42.2
Kavkaz	USSR	42.1
Priboy	USSR	42.1
Maris Templar	England	41.9
Rousalka	Romania	41.5
Bezostaya 1	USSR	41.1
Dacia	Romania	41.1
Baca	Yugoslavia	40.3
Lilifen	Chile	38.7
Moldova	Romania	38.0

* Means over years in which the variety ranked among the highest five in 1000-kernel weight.

Table 14. SUMMARY OF THE DISTRIBUTION OF HIGH PROTEIN - HIGH LYSINE OBSERVATION NURSERIES BY GROWTH HABIT AND NUMBER OF ENTRIES SINCE 1975

Year	Growth Habit	Number of Locations	Number of Countries	Number of Entries
1975	Winter and spring	25	20	280
1976	Winter	28	19	402
"	Spring	16	13	130
1977	Winter	28	19	196
"	Spring	16	13	185

Table 15. MEAN PERCENTAGES OF PROTEIN, LYSINE AND ADJUSTED LYSINE FOR SELECTED LINES AVERAGED OVER 15 LOCATIONS FROM THE HIGH PROTEIN - HIGH LYSINE OBSERVATION NURSERY IN 1975

Variety or Pedigree	Protein %	Lysine %	Adjusted Lysine, %
Highest			
Nap Hal/Atlas 66	22.4	2.75	2.94
" "	21.8	2.76	2.95
" "	20.4	2.83	3.03
Lowest			
CI 13449/Centurk	13.2	3.26	3.26
" "	13.2	3.24	3.27
" "	13.2	3.23	3.24
Check varieties*			
Atlas 66	17.1	2.81	2.97
Lancota	15.4	2.79	2.92
Bezostaya 1	15.4	2.82	2.95
Centurk	14.3	3.01	3.10
CR8156	14.2	2.93	3.01
CII3449	13.4	3.32	3.30

* Means based on four replications at each location.

Table 16. MEAN PERCENTAGES OF LUSINE, ADJUSTED LYSINE AND PROTEIN FOR LINES IN THE HIGH AND LOW LYSINE GROUPS AVERAGED OVER 15 LOCATIONS FROM THE HIGH PROTEIN-HIGH LYSINE OBSERVATION NURSERY IN 1975.

Variety or Pedigree	Lysine %	Adjusted Lysine,%	Protein %
Highest			
Nap Hal/CI 13449	3.48	3.53	13.8
" "	3.44	3.50	14.2
" "	3.41	3.44	14.4
Lowest			
CC-Inia x CNO-Sieti Cerros	2.66	2.87	19.1
Cno^2 - Inia x Bb-CNO	2.65	2,85	17.6
Tob-Cno'S' x Tob-8156/Bb	2.64	2.84	18.0

Table 17. MEAN PERCENTAGES OF PROTEIN, LYSINE AND ADJUSTED LYSINE FOR SELECTED LINES AVERAGED OVER 15 LOCATIONS FROM THE HIGH PROTEIN-HIGH LYSINE OBSERVATION NURSERY IN 1975.*

Entry No.	Variety or Pedigree	Protein %	Lysine %	Adjusted Lysine,%
227	Nap Hal/Atlas 66	20.0	3.05	3.25
167	" "	18.9	3.02	3.21
238	" "	17.9	3.06	3.25
171	Nap Hal/CI 13449	17.0	3.26	3.37
196	" "	16.7	3.15	3.32
239	" "	16.4	3.15	3.30
132	At66/Cmn/ NB69667	16.2	3.07	3.21
259	Nap Hal/CR8156	16.0	3.08	3.24
77	CI13447/3/Lcr/2/At66/Cm	15.9	3.02	3.16

* Lines selected exceeded the nursery grand means for protein and lysine of 15.8 and 3.01%, respectively.

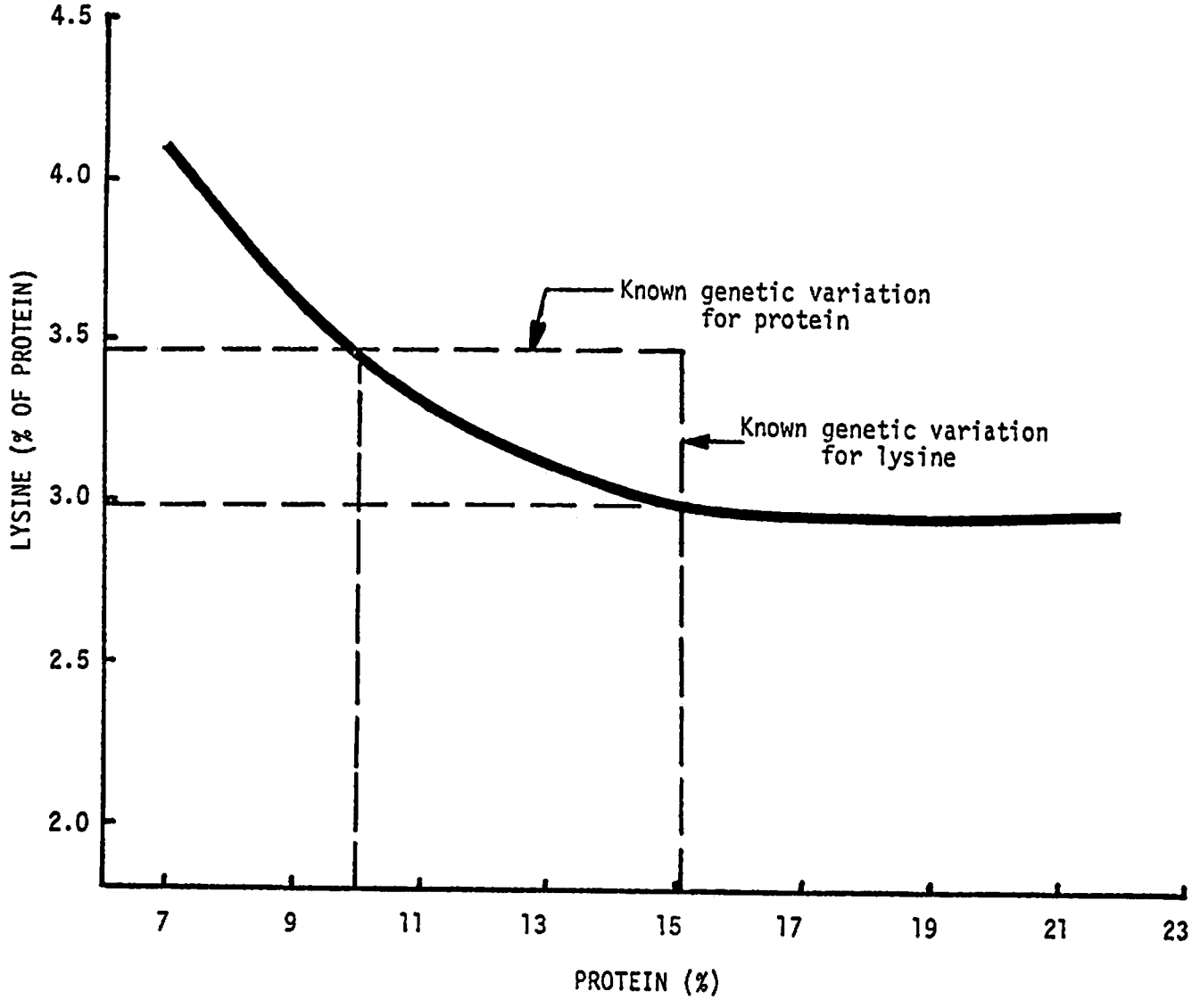

Figure 2. Known genetic variability for protein and lysine in wheat grain should permit development of productive varieties with 5 percentage points higher grain protein and with lysine content equal to that of low protein varieties.

Research results at the University of Nebraska have shown that there is a considerable amount of genetic variability for grain protein content among the wheats of the world. Increases in the grain protein content of wheat are normally associated with depression of lysine per unit protein. The negative curvilinear relationship existing between these two traits is most pronounced in the 11-15% protein range. The known genetic variation of lysine is only of modest magnitude, but is sufficient to overcome the normal depression of lysine with protein increases as shown in Figure 2. By combining the unknown genetic variability of lysine of 0.5 percentage point with the 5.0 percentage points existing for grain protein, it is theoretically possible to develop productive varieties with elevated grain protein levels and with lysine contents equivalent to that of low protein varieties.

References:

1. Stroike, J.E., V.A.Johnson, J.W.Schmidt, P.J.Mattern, and K.D.Wilhelmi. 1974. Results of the Fourth International Winter Wheat Performance Nursery. Nebr.Res.Bul. 265. 159 pages.

2. Stroike, J.E., K.D.Wilhelmi, V.A.Johnson, J.W.Schmidt and P.J.Mattern. 1976. Results of the Fifth International Winter Wheat Performance Nursery grown in 1973. Nebr.Res.Bul. 276. 182 pages.

3. Wilhelmi, K.D., S.L.Kuhr, V.A. Johnson, P.J.Mattern, and J.W.Schmidt. 1976. Results of the Sixth International Winter Wheat Performance Nursery grown in 1974. Nebr. Res.Bul.279. 187 pages.

THE BARLEY RESEARCH PROGRAM OF THE FIELD CROPS SECTION (ACSAD)

By

Dr. L.R.Mosri* and Dr. J.A.Quhaiwi**

Introduction

Breeding high yielding varieties (HYV) has been the major task of many International Organizations and National Programs. Their work which focuses on a few HYV for each country needs to explore the potential of these varieties through identifying the proper cultural practices.

In the dryland farming areas there are few improved local varieties which seem to be promising particularly in drought years.

ACSAD Field Crops Section has carried out some field trials on dates and depths of sowing, and population trials on barley and wheat at Izraa Agricultural Station - South Syria (300 mm average rainfall). It was found that dry and deep sowing (6-8 cm) of both crops gave better yield specially in dry years. The field crops section of ACSAD, which has started its function in 1972, considers crop improvement in those areas of 300-450 mm rainfall in the Arab countries is of vital importance. In addition to barley the section activities cover wheat, grain sorghum and food and feed legumes. Coordination between the Arab Crop improvement programs and ACSAD, has been established. ACSAD is stressing on those programs for the adaptation of further field tests on rotations, cultural practices and agronomy in addition to the breeding aspect.

Current Barley Research Program

The Breeding Program:

Most of the field work of ACSAD is carried out at Izraa, Syria, which has terra rosa soil and mediterranean climate. Some observation lines were distributed for testing in fourteen locations in twelve Arab countries. The following are the details:

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* - Head, Field Crops Section,
** - Director, Plant Studies Division

The Arab Center For The Studies of Arid Zones
and Dry Lands, (ACSAD)
P.O.Box 2440,
Damascus, S.A.R.

(a) The Segregated Populations

The hybridization program started in 1972/73. The segregated population from Syria, Jordan and Lebanon were collected and studied for two years. The seeds of different segregates were sent to the Syrian and Libyan programs for further selections. In their meeting at Benghazi, Libya, in April 1974, the scientists from the Arab countries suggested that ACSAD should produce the F_2 seeds for distributing collaborating programs. Therefore, ACSAD is now producing the F_1 seeds at Deir Alla, Jordan, propagates the seeds in the summer season (same year) at Al-Shoubak Agricultural Station, South Jordan, then distributes the F_2 seeds to the Arab National Breeding Programs. The seeds of few F_2 populations of barley were sent to these programs in 1975/76 and 1976/77 seasons.

(b) The Observation Lines

The Section has started the observation lines since 1972/73. The lines are a composite of local selections from the Arab countries and from regional and international nurseries. 203 lines for 1976/77 seasons have been distributed for testing in Algeria, Egypt, The Emirates, Iraq, Jordan, Libya, Oman, Saudi Arabia, Tunis and Yemen (South and North).

The Observation lines planted at Izraa this season were:

1. The Arabian Barley Observation Lines nursery (203 entries)
2. The Barley Observation Nursery (386 entries)
3. The Preliminary Observation Nursery (PON) of barley (170 entries)
4. The Seventh Regional Crossing Block (RCB) of barley (180 entries).
5. The Segregating Population of barley (105 entries)
6. The Barley Demonstration Lines (118 entries) planted for this Workshop.

(c) Varietal Yield Trials

Two trials of barley were planted this season at Izraa, those are:

1. The Regional Barley Yield Trial (RBYT) received from ICARDA (25 entries, randomized plots, four replications).

2. The Elite Barley Trial (EBT) received from CIMMYT (25 varieties, randomized plots, and four replications).

Suggestions for Discussion

1. Crossing in barley is more difficult than in wheat specially for those who are not well trained. Also barley receives less attention than wheat in most Arab countries. This is why work on barley development is still behind wheat. Therefore, barley breeding in the region should take further considerations. Early maturing and drought tolerant types for the 200 - 300 mm rainfall areas should be introduced. Salinity resistant types should be developed for desert or semi desert areas where soil water salinity constitute a major problem.

2. Besides the traditional breeding methods, ACSAD will use radiation (Gamma rays + Chemical agents), on barley for creating new genetic variability which might bring about a useful material for the arid zones in the Arab countries.

THE BARLEY GERMPLASM COLLECTION PROGRAM (USDA)

J.G.Moseman and J.C.Craddock*

Introduction

The collection, maintenance, and evaluation of plant germplasm has received a considerable amount of attention. The International Board for Plant Genetic Resources (IBPGR) has established an extensive program for collecting and maintaining plant germplasm (1). Many individuals and organizations have emphasized the need for collecting germplasm in regions where the native or land races of germplasm may be disappearing (5). The IBPGR has established regional and crop priorities (2). They have assigned the top priority for collecting germplasm to the Mediterranean, Southwest Asia, Ethiopia, and South Asia regions. Barley has been given a top priority for collection in the Mediterranean and Southwest Asia regions and a third priority in Ethiopia. The IBPGR also has appointed Crop Advisory Committees to advise it on the genetic resource programs for specific crops, and has been cooperating with International Agricultural Research Centers funded by the Consultative Group for International Agricultural Research (CGIAR) (3). Several International Centers have assumed coordinating roles with respect to those crops for which they have the global responsibility. The Centers have cosponsored meetings of the Crop Advisory Committee appointed by IBPGR and have assumed the responsibility for maintenance and evaluation of certain crops. For example, the International Rice Research Institute (IRRI) has agreed to cosponsor the advisory committee for rice and has assumed the responsibility for Indica and Javanica rice (1). The IRRI has developed a standard system for the conservation, evaluation, and utilization of rice maintained in the germplasm collections (4).

The United States Government has long recognized the need for collecting and distributing plant materials. In 1827, President John Quincy Adams instructed the U.S. Foreign Service Officers to

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"collect and transmit seed and plants to the United States." In 1839, Congress appropriated one thousand dollars for collecting and distributing plant materials to agriculturalists. In 1862 the U.S. Department of Agriculture was established and the program for plant exploration was expanded. Since 1898, when the Section for Seed and Plant Introductions was established, some unit within the U.S. Department of Agriculture (USDA) has been responsible for the collection and distribution of plant germplasm (6).

The Plant Genetics and Germplasm Institute was established at the Beltsville Agricultural Research Center in 1972. There are research projects in that Institute concerned with the introduction, distribution, maintenance, evaluation, and improvement of germplasm of many crops. We will describe only the research program associated with the USDA barley germplasm collection, which is part of the USDA Small Grains Germplasm Collection program in the Germplasm Resources Laboratory, Plant Genetics and Germplasm Institute.

Role, Objective and Composition of Collection

The USDA Small Grains Germplasm Collection, which includes wheat, oats, barley, and rye is part of the national plant germplasm system. The system consists of institutes and research units in the United States which cooperate in introducing, maintaining, evaluating, and documenting information on germplasm of several crops. The Principal Plant Introduction Officer, who is responsible for coordinating the introduction and exchange of plant germplasm between scientists in the United States and other countries, is in the Germplasm Resources Laboratory. The introduced germplasm is sent to designated institutions or individuals who are germplasm curators of specific crops. Dr. J.C. Craddock is the curator of the USDA Small Germplasm Collection. The curators are responsible for maintaining, distributing, evaluating, and documenting information on the germplasm of the species for which they are responsible.

The primary objective for the USDA Small Grains Germplasm Collection program is to furnish seed of accessions with desirable characteristics to scientists developing stable, high yielding, good agronomic, high quality, pest and stress resistant cultivars to increase the world food supply for the increasing world population. Most requests for germplasm are received from plant breeders and other scientists interested in cultivar improvement. Some requests are received from scientists conducting fundamental or basic research because of the genetic and other information available on the accessions.

The number of accessions in the Small Grain Germplasm Collection has increased rapidly in recent years. There were 16,000 accessions in the Collection when it was established in 1948. There are now more than 70,000 accessions, of which 48% are Triticum, 27% Hordeum, 22% Avena, 2% Secale, and less than 1% Aegilops. About 150,000 samples of 5 grams each are distributed annually without charge. In 1973 samples were sent to 151 individuals in 29 countries and to 142 individuals in 30 States in the United States.

Sources of Accessions

The barley accessions have been obtained from plant explorations, plant breeders, other scientists, and curators. There are 2,498 accessions from Ethiopia- 3,178 from Israel; and 1,261 from Turkey in the barley collection. Most of those accessions were obtained from plant explorers. A special small grains exploration trip to South America is planned for 1978. Barley germplasm is being obtained from a PL 480 project in Yugoslavia and a U.S./Israel Binational Science Foundation project in Israel. A few accessions are obtained directly from plant breeders and other scientists. Those accessions are usually outstanding for specific characteristics or are new varieties. Arrangements are being made to exchange accessions with curators of the N.I. Vavilov All- Union Institute of Plant Introduction (VIR) in Leningrad, U.S.S.R. and the Laboratorio Del Germoplasma in Bari, Italy.

Maintenance of Accessions

New introductions are incorporated into the collection as accessions in the following manner:

1. Introductions from other countries are assigned Plant Introduction (PI) numbers at the USDA Plant Germplasm Quarantine Center (formerly the USDA Plant Inspection Station).

2. Introductions, usually breeding lines or new varieties, from within the United States are assigned Cereal Identification (CI) numbers.

A "museum sample" consisting of the original seed packet and a few seeds of each new introduction is stored permanently for comparative purposes. The following information is documented on each new introduction: Plant Introduction (PI) and/or Cereal Identification (CI)

number, genus, species, variety name, station number, seed source and origin (collector, breeder, agency, and country providing the sample), and any unique characteristics.

All introductions from other countries are grown in detention for at least one generation and inspected by a representative in the Animal and Plant Health Service (APHS), formerly the Animal and Plant Health Inspection Service (APHIS), to avoid the introduction of new pests before they are included as accessions in the Collection. Approximately 10 spikes of each new accession are preserved as herbarium specimens. Two samples are taken from the first generation increase of each introduction before the harvested seed is added as an accession to the Collection. One sample is for the seed repository at the National Seed Storage Laboratory, Fort Collins, Colorado, as a precaution against future loss. The other sample is for inventory renewal. The latter sample provides a means for minimizing genetic changes and/or the accumulation of mechanical mixtures during subsequent seed increases. The remaining seed is available for distribution.

The seed is stored in a controlled environment of approximately 50 percent relative humidity and 10 degrees centigrade. Germination of at least 85 percent is acceptable. The seed is replenished when the stocks are reduced to 100 grams or less. Two nursery sites--one at Aberdeen, Idaho, and the other at Mesa, Arizona--are used for increasing seed. The nursery at Aberdeen is for spring sown grains, and the nursery at Mesa is for fall sown grains and for growing new introductions in detention. The nursery at Mesa is sufficiently isolated from major small grain producing areas to minimize the escape of pests, and the climate is suitable for growing winter and spring types.

Distribution of Accessions

All seed in the collection is open stock and is sent without charge to any scientist, individual, or institute which requests seed for use in barley improvement. Five grams of seed of each accession requested is furnished. However, when sufficient seed is available, more than 5 grams per accessions may be furnished for special purposes. When an accession is requested which is not in the collection, arrangements are made for obtaining that seed. If necessary, a special supply of seed may be increased for that individual.

Evaluation of Accessions

The accessions in the barley collection have been and are now being evaluated by many cooperators. Fourteen individuals receive the new barley accessions annually to test for pest resistance, nutritional quality, agronomic characteristics, and other traits. Cooperators who receive accessions from the collection are encouraged to return the information they obtain for incorporation into the information data bank. The information in the data bank is supplemented with published and unpublished information furnished by individuals who have tested accessions for specific characteristics. This information is available for use in other research projects. For example, those data have been used in developing sets of "elite germplasm" which are available for the following characteristics: resistance to powdery mildew, leaf rust, scald, net blotch, spot blotch, Barley Yellow Dwarf Virus, and oat cyst nematode- feed, malting and winter types; and short straw. Each set of elite germplasm contains accessions from the collection which have been found to be outstanding for a specific characteristic or combinations of characteristics. Individuals requesting accessions with specific characteristics are often furnished a set of elite germplasm for those characteristics. The use of elite germplasm sets has greatly reduced the number of accessions we furnish cooperators and the cooperators obtain accessions with the required characteristics for their research without having to test the entire collection.

Documentation of Data

Data obtained on the accessions in the collection are being computerized in cooperation with the Agricultural Research Service. Data Systems Applications Division at Beltsville. Computer programs have been developed to retrieve, compile, summarize, and analyze the information on the accessions in the collection. The following information is available on most of the accessions: Plant Introduction and/or Cereal Identification number, genus, species, variety name, station or selection number, seed sources, and origin. Some data on evaluation of accessions obtained by cooperators has been included in the information data bank, but much more data are available for inclusion in that bank.

Expansion of Program

A scientist is being added to the staff of the USDA Small Grains Germplasm Collection program. This scientist will be responsible for the evaluation of accessions and management of data. The duties will include (1) determining characteristics to be evaluated, procedures for

conducting evaluations, and descriptors to use in evaluations; (2) arranging for evaluations by cooperators and acquiring the evaluation data; (3) developing sets of elite germplasm with specific characteristics or combinations of characteristics; (4) arranging for obtaining data in computerizable form and the compilation, computerization, summarization, analysis, and interpretation of that data.

Barley Germplasm Collection

Barley germplasm collections are being maintained in several countries. In addition to the USDA Barley Germplasm Collection, the following are institutes and countries which have large barley germplasm collections: N.I. Vavilov All-Union Institute of Plant Introduction (VIR) in Leningrad, USSR; Waite Agricultural Research Institute, Adelaide, The Crop Research and Introduction Centre, Izmir, Turkey; Zentralinstitut for Genetik and Kulturpflanzenforschung, 4325 Gatersleben, German Democratic Republic; and the Laboratorio Del Germoplasma, Bari, Italy.

Individuals interested in barley improvement should be concerned with the conservation of barley germplasm, since genetic diverse germplasm is the foundation of barley variety improvement programs. Barley germplasm is rapidly disappearing in some countries in the Mediterranean Area, Central Africa, Asia, and South America. Barley germplasm should be collected immediately and conserved in those regions before it is lost forever. The International Board for Plant Genetic Resources (IBPGR) and other international agencies should be encouraged to support barley germplasm programs in those countries where barley is an important food or feed crop.

References

1. The conservation of crop genetic resources, 15p., 1975. Consultative Group on International Agricultural Research, International Board for Plant Genetic Resources, Rome, Italy.

2. Priorities among crops and regions, 24p. 1976. Consultative Group on International Agricultural Research, International Board for Plant Genetic Resources, Rome, Italy.

3. Annual report 1975. 21p. Consultative Group on International Agricultural Research, International Board for Plant Genetic Resources, Rome, Italy.

4. Chang, T.T. 1976. Manual on genetic conservation of rice germ plasm for evaluation and utilization. International Rice Research Institute, Los Banos, Philippines.

5. Harlan, J.R., 1975. Our vanishing genetic resources. SCIENCE 188: 168-621.

6. Moseman, J.G., and J.C.Craddock, 1975. Genetic basis for collecting, evaluating, and maintaining barley germplasm. In Barley Genetics III, 849p., Verlag Karl Thiemig, Munchen, Germany.

THE OREGON STATE UNIVERSITY INTERNATIONAL NURSERY PROGRAM

W. L. McCuistion*

An overall objective of the expanded Winter x Spring Wheat Program here at OSU is to increase wheat production in winter rainfed areas. More specific objectives are the creation of additional genetic variation for use in strengthening national cereal research programs in Oregon and the developing countries. Winter and spring wheats have historically been developed separately. For this reason the crosses between the two groups provide highly variable germplasm. The reason for not mixing these two large wheat groups during early years was due to the difficulty in growing the spring wheats in the winter wheat area and vice versa. Only in specific cases were spring and winter wheats crossed under greenhouse conditions when a certain desired character was being transferred from one group to another. Some varieties that resulted from this type of crossing were the following:

Wheat Varieties From Winter X Spring Crosses:

Year	Variety	Pedigree
1924	Ridit	Turkey x Florence
1924	Reliance	Kanred x Marquis
1933	Rex	White Odessa x Hard Federation
1934	Thatcher	Marquis-IumilloxMarquis-Kanred
1942	Federation 41	(Martin x White Federation)^{3}x Federation^6
1950	Norin 10-Brevor	Used as source of dwarfism in spring wheats

The spring wheat variety Hope was used extensively to transfer stem rust resistant genes into winter varieties and selections. The winter x spring crosses which received the greatest attention were the semi-dwarf varieties which gave rise to the so-called Green Revolution. These crosses resulted from the use of the dwarfing genes from the winter selection Norin 10 - Brevor in combination with the daylength insensitive spring wheats.

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The late Dr. Joseph A. Rupert initiated a series of winter x spring wheat crosses while cooperating in the Chilean national wheat improvement program. Upon returning to the United States in the fall of 1968, he was able to spend full time in development of winter x spring wheat germplasm. The entire program was then transferred to Corvallis, Oregon in 1971 where climatic conditions made it much easier to manipulate the winter and spring wheat material. The overall objective, of course, is to increase wheat production in winter rainfed areas. Close collaboration has continued with Oregon State University and CIMMYT during the past several years and CIMMYT requested that OSU serve as the center for development and distribution of winter wheat germplasm to cooperators throughout the world. The specific objectives of the winter x spring wheat program are to create genetic variability, to exchange germplasm and information and establish lines of communication between wheat breeders.

A cooperative program between Oregon State University and the Government of Turkey resulted from Dr. Warren Kronstad's consulting missions and made it possible for scientists from the university to work in cooperation with the Turkish government over a period of six years. Simultaneously, the Rockefeller Foundation and CIMMYT helped establish a Wheat Research and Training Center in Ankara which has greatly aided in the development of cereal research in the country of Turkey. An important graduate training program was also added to the overall efforts of research development.

The CIMMYT staff make all of the initial winter x spring F_1 crosses in Mexico. The F_1's are then top and double crossed back to spring types for continuation in their selection program at CIMMYT. Screening for the three rusts at the two locations in Mexico are ideal due to both natural and artificial development of the rust spores. Members of the OSU cereal staff visit the nurseries at Obregon during harvest to select germplasm for use in a continuing program in Oregon. This also provides an opportunity to remain abreast of the newest developments in the spring wheat program.

Ample seed of the F_1 populations are sent to Oregon for seeding and evaluation in the winter nurseries. The F_1's are top and double crossed back to winter type wheats and then screened for agronomic traits and disease resistance. Of specific interest in the winter wheat program are winterhardiness and drought resistance. The diversity in climates within the State of Oregon allows screening for most of the specific climates encountered throughout the winter wheat regions of

the world. The Willamette Valley where Oregon State University is located between the Pacific coast and the Cascade mountains has an annual rainfall of approximately 1000 mm and a mediterranean climate. Occasional freezing temperatures and late frosts can be encountered. The Pendleton Station in extreme northeastern Oregon has an annual rainfall of approximately 500 mm with freezing temperatures and higher altitude. Agriculture in this area is one of cereal-legume rotation. The third major site is the Sherman Experiment Station located just to the eastern side of the Cascade range with an annual rainfall of approximately 200 mm which requires a wheat-fallow rotation system with moisture conservation being critical. Freezing temperatures are common and the winds with blowing snow occur at frequent intervals during the winter months.

Additional stations for winter wheat are located under irrigated conditions, low temperatures for measuring winterhardiness and late frosts extending into the summer months. All of the major diseases of wheat with the exception of stem rust occur naturally at some location throughout the State of Oregon. For this reason it is possible to screen the germplasm for specific resistance.

There is a high degree of genetic diversity within and between the spring and winter wheat groups providing opportunity to transfer many important characters from one type to another. One of the present objectives, for example, is to combine the earliness of spring wheat with winterhardiness of the winter wheats for areas in the northern hemisphere with very cold winter temperatures and dry conditions during late spring.

The most outstanding cultivars from the selection process are included in preliminary yield trials after which a group of 250 advanced lines are entered in the International Winter X Spring Wheat Screening Nursery. This nursery is presently being grown in over 80 locations throughout the world. All major market classes of wheat except durum wheat are being included in the nursery. The most recent 5th IWSWSN contains the following numbers of lines in each of the major market classes.

Table 1. Number of Advanced Lines of Each Market Class of Wheat in the 5th IWSWSN for 1977-78 Crop Season.

Market Class	No. of Lines
Hard Red Winter	70
Hard White Winter	29
Soft Red Winter	52
Soft White Winter	61
Segregating Red - White	21
Checks	17
Entries	250

Instructions for the management and reporting of results for the screening nursery are sent to each cooperator in order that standardization is possible in reporting all data. The computer is used to summarize the data from all locations and the results are printed immediately for return to cooperators before their next crossing season. Approximately 70 percent of the cooperators have been returning data for the first three screening nurseries. This is very good considering that many locations either lost the crop due to adverse weather conditions or the seed was not received in time for the crop.

All data received is reported in the summary tables. In addition, the top 25 lines from each location are reported in a location table. Overall summary tables are presented for the best 25 lines for each of the following agronomic characters and diseases: Yield, earliness, winterhardiness, *Puccinia graminis tritici*, *Puccinia recondita*, *Puccinia striiformis*, *Septoria tritici*, *Erysiphegraminis tritici* and superior agronomic performance over all locations. The highest yielding and earliest maturing lines are reported in tables 2 and 3, respectively.

The final summary tables are composed of the best 25 lines in each of three zones based on total rainfall during the crop season. Zones 1, 2 and 3 are 400 mm, 400-650 mm and 650 mm, respectively.

Table 2. Highest Yielding Lines Over All Locations Reporting On 3rd IWSWSN - 1975-76.

Entry No.	Pedigree	Average Yield (Kg/ha)
343	CLLF/BEZ/3/SU 92/CI 13645//NAI	5850
315	FN/3*TH//K58/N/3/MY 54/N10B// AN S/4/ANZA	5747
356	AU/ANZA	5580
382	HYS S/7C	5449
297	YT 54/N10B//NAR 59 S/3/HYS	5347
2	BEZOSTAJA - CHECK	4952

Table 3. Earliest Maturing Lines Over All Locations Reporting On 3rd IWSWSN - 1975-76

Entry No.	Pedigree	Days From Jan. 1
327	SU 92/CI 13645//ON/3/TOB	129
322	NAI/ANZA	129
290	SU 92//AN/SDY	130
295	TMP/CI 12406//OL	130
312	SU 92/CI 13645//INIA	131
121	AN//S64/SS 2	133
3	LERMA ROJO - CHECK	131
2	BEZOSTAJA - CHECK	146

Table 4 lists the number of locations in each rainfall zone that reported specific cultivars in the top 25 entries at their respective location.

Table 4. Number of Locations in Each Rainfall Zone Reporting the Respective Advanced Lines in Top 25 Entries - 3rd IWSWSN - 1975-76.

Entry No.	Pedigree or Check Variety	Zones		
		1	2	3
34	CNO S/INIA S//HN VII	1	3	3
107	STC/CLLF//CNO/INIA/3/BB S	4	4	1
323	NAI/ANZA	3	1	3
343	CLLF/BEZ/3/SU 92/CI 13645//NAI	4	3	1
344	CLLF/PCH//KOL	4	4	1
382	HYS S/7C	3	0	3
397	NOR/6720//BEZ	1	4	3
3	LERMA ROJO	2	2	0

The OSU cereal improvement program also includes winter x spring crosses in barley and triticales. Both malting and feed grain barleys are receiving strong emphasis. Germplasm from this program is being distributed to cooperators upon request. A new grant from the Rockefeller Foundation has allowed expansion of the winter triticale breeding effort. The feed grain program also includes wheat and some work in sorghum. Training is one of the most essential components of the cereal improvement program at OSU. With the large number of international students attending the university, it is important to maintain flexibility in programs but not to reduce the overall standards. It is essential that leadship skills be developed and that a professional attitude be instilled in the minds of the students. The training program must be geared to the needs of the international students in order that they be prepared for scientific research in their respective countries.

The present esprit de corps among cooperators in cereal improvement throughout the world is commendable. A team approach to the development and exchange of new germplasm and technology is certain to result in dividends for all countries involved in international cooperation.

THE SVALOF BARLEY BREEDING PROGRAM

By

Arne Hagberg*

The cereals are dominating among the crops and barley is the most important individual crop in Sweden.

During the last ten years, the Svalof barley breeding program has been intensely studied with regard to the food and feed value (nutritional aspects). In addition, it has also studied the problems of yield improvement, better disease resistance and a more widely adapted barley.

It is evident that the breeding program must concern itself with nutritional aspects as more than 90% of the crop is used for food or feed (mainly feed about 8% being used for malting).

Barley has also been used as a model crop in mutation research and of course the induced mutations have been utilized in the breeding program and from this program many mutation studies have been initiated. Intensive studies on the genetics and cytogenetics of induced barley mutations and structural changes have yielded some good tools and good information valuable for further breeding. This is especially true for the hybrid barley program but also for the studies on high lysine barley as well as mildew resistance, etc.

Genetics of high lysine genes

Two genes for high lysine have been selected for use in the barley breeding program Hiproly (lys 1) and Risø 1508 (lys 2), K.E.Karlsson (1976) found the lys 1 gene to be located in the long arm of chromosome 7 between the marker genes "s" and "r." From linkage studies on lys 2 and a set of reciprocal translocations it is evident that lys 2 is also located on chromosome 7 but in the centromere region possibly proximally in the short arm, as the lys 2 gene is strongly linked with translocations in both chromosome arms. On the other hand there is a free segregation between lys 2 and the gene "s" and between lys 2 lys 1. (Table 1 and Fig. 2). In Hiproly, lys 1 is linked to "s". Back crossing lys 1 to high yielding genotypes with SS is desirable to obtain

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recombination products with the cross over as close as possible to the lys 1 gene. This can be easily controlled for the genes s and r in the back cross program for lys 1. It has been possible to break the combination of high lysine and shrunken seed in Hiproly. However, from the linkage studies as well as from the conventional breeding work it seems to be more difficult to separate the high lysine character from Risø 1508 from the shrunken seed character; all high lysine recombinants obtained also having shrunken seed. Table 2. (K.E.Karlsson, 1977). For this reason the breeding program is now concentrated on Hiproly and lys 1 material inspite of the fact that Hiproly itself is a poor yielding material under Swedish conditions (Table 3, G. Persson, 1976).

Progress in breeding high lysine barley

The yield of Hiproly itself is about a third that of the standard variety. The Risø 1508, however, has about 75% yield compared to standard (Table 4). The first hybrids with lys 1 showed some improvement or about 2/3 of the standard. After about five back crosses a yield level of about 90% of standard was reached in grain production. The grains were somewhat smaller but not shrunken as in the original donor line. The recurrent parent was mona. For the possibility of increasing seed size the back cross lines were crossed to large seeded varieties like Birgitta. Unfortunately, the lines selected were not improved with regard to seed size, contrary to our expectations(Table 5.). Some other crosses, however, are giving rather promising lines yielding just as much grain as the standard and with a considerable increase in lysine yield (Table 6.). Conventional breeding is also producing high lysine lines with ss or SS which are equally successful. (Table 6.). The breeding work can be illustrated by the diagrams in Fig. 3, 4 and 5 showing the difficulties in obtaining high enough yielding lines. It may be necessary to select for high lysine genotypes at a normal and relatively low protein content. It may be possible to reach this goal in a first step and then try to increase the protein content of this new qualitatively well balanced type. So far most of the selection efforts have attempted to achieve higher protein content as well as a better protein quality (G.Persson and K.E.Karsson, 1976). Feeding experiments confirm the value of the high lysine material (Table 7) demonstrated in many experiments by Eggum, Madsen, Thomke, etc.

Assimilate incorporation in grains of high lysine genotypes

Evidently it is difficult to find high lysine genotypes which produce as large and well filled grains as do genotypes with a conventional amino acid composition of endosperm protein. It is important for the breeders aiming at improved protein quality in new barley varieties to know the reason why grain filling is inferior in high lysine genotypes compared to low lysine types. With this knowledge it might be possible to apply an efficient selection pressure on populations segregating for high lysine genes using an adequate screening technique. So far breeders are just screening for well filled grains with high lysine and this might be sufficient. Anyhow, a better understanding of the actual problems from a physiological and biochemical point of view would be preferred and would possibly lead to a more appropriate screening procedure.

At the Svalof institute some preliminary investigations are done on material grown in growth chambers under fully controlled conditions (V. Stoy and R. Olered, 1976). Four pairs of high lysine barley genotypes - three of them including lys 1 from Hiproly and one lys 2 from Risø 1508 - and corresponding low lysine genotypes are being compared with regard to incorporation of dry matter starch and protein and simultaneously occurring changes in amylase activity in the grains are studied. Also the incorporation of 14C-labelled suchrose in grains of different genotypes and age is being studied.

The dry matter incorporation - dry matter growth - in ripening grains was inferior in all high lysine genotypes compared to corresponding normal material except for the most advanced "back cross line" where no difference was found. The same situation was true for the absolute amount of starch per grain.

The proportion of starch (in percent of dry matter) was significantly lower in Hiproly and Risø 1508 than in corresponding normal material, while there was no difference between the two back cross lines compared to respective standard material. Evidently it is the growth of grain which is somewhat inhibited in the back cross lines while the proportion of starch is not reduced as it is in the Hiproly and Risø 1508 material. It is evidently possible to transfer the gene for high lysine to another genotypic background and have another phenotypic expression of the gene lys 1.

The determinations of amylase activity at different stages of grain development indicate that the Hiproly and Risø 1508 have a low starch proportion because of high amylase activity and breakdown of starch. This situation seems to be more severe in case of Risø 1508. The differences found in ^{14}C-labelled suchrose incorporation seem to confirm the results based on the high -amylase activity in Risø 1508. These investigations are continued and need further evidences for confirmation. A better understanding of the incorporation problems in different high lysine genotypes is greatly needed.

Investigations on Triticale and Rye

The problems of shrunken seed and also of high -amylase activity in the ripening seed are often met with in Triticale. Thus, some basic problems of grain filling might be related to those met with in high lysine barley. In an intensive breeding of Triticale it seems possible to improve seed size and seed shape considerably and very promising material is now at hand. In this connection it is important to investigate the variation in amino acid composition of Triticale protein. H. Johansson and A. Marker have studied the DBC-values and plotted them against the crude protein content determined by Kjeldahl method. The results are found in Fig. 6 (spring types) and Fig. 7 (winter types). There is no doubt a larger variation in lysine content in Triticale than in wheat and also the level of lysine content in protein is much better; in some cases it is just as good as in high lysine barley based on the lys 1 gene. It is, of course, tempting to try to transfer this positive variation to wheat. Such efforts are now being done since the variation so far found in wheat with regard to lysine content is very small.

Even in rye there seems to be an interesting positive variation in lysine content (Fig. 8). However, this result needs confirmation by a second or more generation of lysine tests. Rye being a cross fertilizer it is necessary to deal with the material on an individual plant basis with self-compatible material or with controlled crosses between identified high lysine parent plants. The problem of identifying the individual high lysine plants (before flowering) in the large populations, that you have to deal with, is a very laboureous one. When the plants are analysed in the laboratory and the high lysine ones are identified, it is too late to make the crosses you need to establish a high lysine population. Anyway, it seems possible to establish a high lysine population of rye even if the results so far obtained are only preliminary.

It is also shown by E. Holmberg (pers. comm.) that it is possible to establish a rye population with a considerable decrease in 5-alkyl-resorcinols which are of importance as anti-nutritional compounds. Thus, it is possible to use this new rye material in the production of new triticale material which, if desirable, can be further transferred to wheat substitution lines eventually to increase interesting variation available for wheat breeding.

The FAO/SIDA/SAREC Project on improvement of nutritional quality in barley and spring wheat

The aim of the project is to establish cooperation in a breeding program on nutritional quality in barley and spring wheat between the Svalof breeding institute and six institutes in developing countries, five of them within the FAO/UNDP Regional Project on Field Food Crops in the Near East and North Africa; Indian Agricultural Research Institute (IAR), New Delhi, India; Punjab Agricultural Research Institute (PARI), Lyallpur, Pakistan; Seed and Plant Improvement Institute, Karaj, Iran; Field Crop Research Institute, Agricultural Research Center, Giza, Egypt; Holetta Agricultural Research Station, Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia, and Regional Agricultural Research Institute, Ankara, Turkey. The project was put into operation 1st July 1975 after FAO had agreed with the Swedish Government for this joint research program.

The total budget for the first phase of the project - 1st July 1975 - 30 June 1979, is 7.4 million Swedish Crowns (equal to 1.7 million US Dollars).

Training program

An important part of the project is the cooperation between the seven participating institutes. Two trainees from each institute, one in plant breeding and one in biochemistry, were trained in 1976 and 1977. The training program started in June 1975.

This program has established contacts with several institutes and industries in Northwest Europe as the Agricultural College in Sweden and in FAO and other cooperating institutes in Denmark, Norway, Germany and England. The main work of the trainees is to participate in the breeding program and learn every detail in the procedure.

The second training period, March-October of this year, has just started with Rashad A. Abo-Elenein, Abdo and Nabih A. Ibrahim, Egypt; Hailu Gebre and Addissie Nuramo, Ethiopia; and Abdul Qadir Basgul and Ayhan Atli, Turkey.

Seminars

In order to strengthen the cooperation within the project, annual seminars are planned. The first seminar was held at Svalof in October of last year. This gave good opportunities for Directors and Senior Cereal Breeders in charge of the project at the cooperating institutes to meet and discuss with FAO experts, breeders and nutritionists working in the field.

Inventory program

In a breeding program for high lysine in cereals it is essential that several high-lysine genes have been identified in order to find good combiners of high yield and optimal lysine production at a level where hopefully lysine no longer will be the first limiting amino-acid. Therefore, an inventory screening for new high-lysine and high-protein genes is another major part of the program.

Included in the spring barley for inventory of protein quality harvested the summer 1975 were 950 varieties and 1976 6,300 varieties from Turkey, USA (Beltsville) and West Germany (Max Planck Institute). The Institute of Genetics, University of Lund and the Barley Mutation Program at Svalof has placed about 30,000 M_2 progenies (EMS, X-ray, neutrene and other treatments) at the disposal of this project.

The inventory program in wheat is still more intensive than in barley. Altogether, more than 19,000 entries of wheat and more than 35,000 entries of barley have been introduced for assessment of protein quality. Of the inventory material, more than 7,000 entries of wheat and more than 4,000 entries of barley have so far been analyzed for dye-binding capacity and protein content.

Breeding program

The first crosses and backcrosses have been made in the barley breeding program. One generation has been grown this winter in Latin America. F_2's from one, two or three backcrosses to the lysine gene receptors will be sown in Svalof this spring. Donors of

the high-lysine genes are Sv 73608 (=Hiproly x Mona[5]) and Risø 1508. Two to four receptors of the high-lysine genes are used per country:

India	:	DL-70, Himani, Ratna and Joyti
Pakistan	:	Barley 4342 and 5681
Iran	:	Zarjo, Eram and Sina
Egypt	:	Giza 119, Sahrawi and Bonus
Ethiopia	:	Composite 29, C63 and Kenya Research
Turkey	:	Cumchuriat 50, A-147 Streng's Frankengerste and Tokak

Similarly the wheat breeding program is performed.

F_2 material will be grown in Svalof this summer and next generation will be grown at all cooperating institutes. For a breeding program it is extremely important to have the newest released and best available market varieties, as well as promising breeding lines. As soon as new ones are available, they will be integrated in the breeding program. This autumn after harvest, when the second group of trainees are returning home, the material will be sent to the cooperating institutes to continue the breeding program. Next winter, chemical equipment for DBC and Kjeldahl analysis will be functioning in the laboratories of all the participating institutes.

Eventual cooperation with EBC Barley Committee

Among international organizations dealing with barley the Barley Committee of the European Brewery Convention might be mentioned. The Barley Committee is organizing a uniform testing system of new barley varieties in Europe using spring barley as well as winter barley. All information is collected and reported through the European Barley Information System (EBIS). May be it should be investigated if some cooperation with EBIS and the EBC Barley Committee is useful. A few members of this committee are attending this workshop and the Barley Committee will meet in Spain next week. Thus, a decision of cooperation can be taken without any delay.

Literature cited:

Doll, H. 1973. Inheritance of the high lysine character of a barley mutant. Hereditas 74:293:294

Hagberg, A. and Karlsson, K.E. 1969. Breeding for high protein content and quality in barley. IAEA/FAO, STI PUB 258, Vienna.

Johansson, H. 1977. Improvement of nutritional quality in barley and spring wheat. FAO/SIDA/SAREC Project TF INT 112 (SWE) Proc. IAEA Baden - meeting in April 1977.

Karlsson, K.E. 1975. Linkage studies on the Lys-gene in relation to some marker genes and translocations. Barley Genetics III, Garching.

Karlsson, K.E. 1977. Linkage studies on a gene for high lysine content in Risø barley mutant 1508. Barley Genetics Newsletter, Vol. 7.

Persson, G. and Karlsson, K.E. 1976. Progress in breeding for improved nutritive value in barley. Report to Eucarpia Cereal Section Meeting, Cambridge.

Table 1. Segregation of high lysine content and semisterility in crosses between translocations and Risö mutant 1508.

Combination	Normal lysine Semisterile	Normal lysine Fertile	High lysine Semisterile	High lysine Fertile	Total	χ^2_L	Percentage recombination
T2-3f x Risö mut.1508	115	113	35	36	299	0.03	free
T2-7b x - " -	140	82	1	53	276	55.31**	1.06 ± 0.86
T3-7c x - " -	135	106	0	54	295	41.22**	0.00
T3-7d x - " -	162	69	0	61	292	86.96**	0.00
T4-6e x - " -	53	43	12	3	111	0.87	free

** Significance on the level of P 0.001

Table 2. Segregation of high lysine content and shrunken seeds in crosses between translocations and Riso mutant 1508.

	Normal lysine Plump seeds	Normal lysine Shrunken seeds	High lysine Plump seeds	High lysine Shrunken seeds	Total	χ^2_L	Percentage recombination
Pooled material from the combinations reported in table 1	1018	0	0	255	1273	958.01**	0.00

** Significance on the level of P 0.001

Table 3. Results from field experiments involving primary crosses with Hiproly

Variety	Yield kg/ha	Yield rel.	Protein content %	Protein yield kg/ha	Protein yield rel.	Lysine content g/100 g protein	Lysine yield kg/ha	Lysine yield rel.
Ingrid	6952	100	12.3	855	100	3.60	31	100
22075	4008	58	13.2	529	62	3.97	21	68
22224	3608	52	13.0	469	55	4.30	20	65
22275	5040	72	11.6	575	67	4.27	25	81
22371	3160	45	15.7	496	58	4.32	21	68
223o8	4728	68	13.0	615	72	4.19	26	84
Hiproly	2664	38	16.4	437	51	4.19	18	68

Table 4 YIELD CHARACTERS FOR TELLUS AND RISØ 1508

VARIETY	1.000 GRAIN WEIGHT G	GRAIN YIELD KG/HA	GRAIN YIELD REL	PROTEIN % IN SAMPLE	PROTEIN YIELD KG/HA	PROTEIN YIELD REL	LYSINE G/16GN	LYSINE YIELD KG/HA	LYSINE YIELD REL
TELLUS	51.7	6251	100	11.55	722	100	3.45	24.9	100
RISØ 1508	44.4	4682	75	13.30	623	86	5.17	32.2	129

Table 5. Yield and grain characters for high lysine selections in the cross Mona^{bc} x Birgitta.

Variety	Protein %	DBC	Relative yield I=100 Seed	Relative yield I=100 Protein	Tgw	Hlw
Ingrid	11.10	46.35	100	100	39.2	72.0
Sv 76452	13.65	53.40	80	99	33.9	68.9
Sv 76453	12.70	52.20	87	100	34.4	68.9
Sv 76455	13.10	52.55	87	103	37.6	68.6
Sv 76457	12.85	51.15	92	107	38.0	68.3
Sv 76458	11.25	49.70	91	93	44.8	70.9
Sv 76459	13.05	52.25	87	103	38.5	69.6
Sv 76460	12.65	52.10	83	95	37.5	67.4

Table 6 Yield characters for high lysine selections

Variety	Rachilla Hairs	Protein %	Lysine % of protein	DBC	Relative yield Ingrid=100		
					Seed	Protein	Lysine
Ingrid	SS	11.4	3.55	47.05	100	100	100
Sv 74863	ss	12.3	4.29	51.60	96	103	125
Sv 74865	ss	11.3	4.44	49.85	96	95	119
Sv 75227	SS	11.3	4.11	48.95	99	98	114
Sv 75229	SS	12.0	4.17	50.60	96	101	119
Sv 75232	ss	11.8	4.20	49.70	99	102	121
Sv 75235	ss	11.5	4.36	49.80	99	100	123
Sv 75237	ss	11.7	4.18	50.30	98	101	118
Sv 75238	SS	12.0	4.16	51.05	99	104	122
Sv 75240	SS	12.2	4.17	50.15	99	106	125

Table 7 Results of pig experiments, 5 animals/treatment, Ultuna

	Type of barley			
	Hiproly	Ingrid	Ingrid	Ingrid
Protein conc. %	2	2	2	10
Syabean oilmeal %	-	-	5.2	-
Average daily gain, g	523	461	491	538

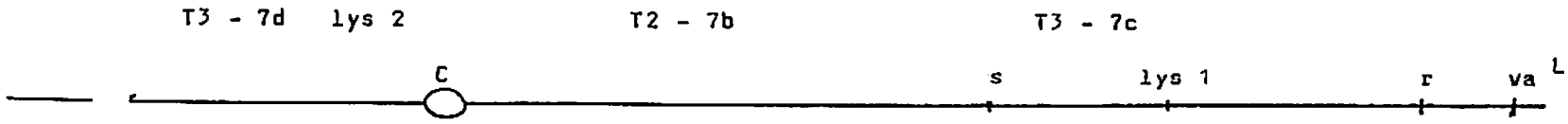

Fig. 2. Some linkage data for barley chromosome 7 indicating the possible positions of some high lysine genes.

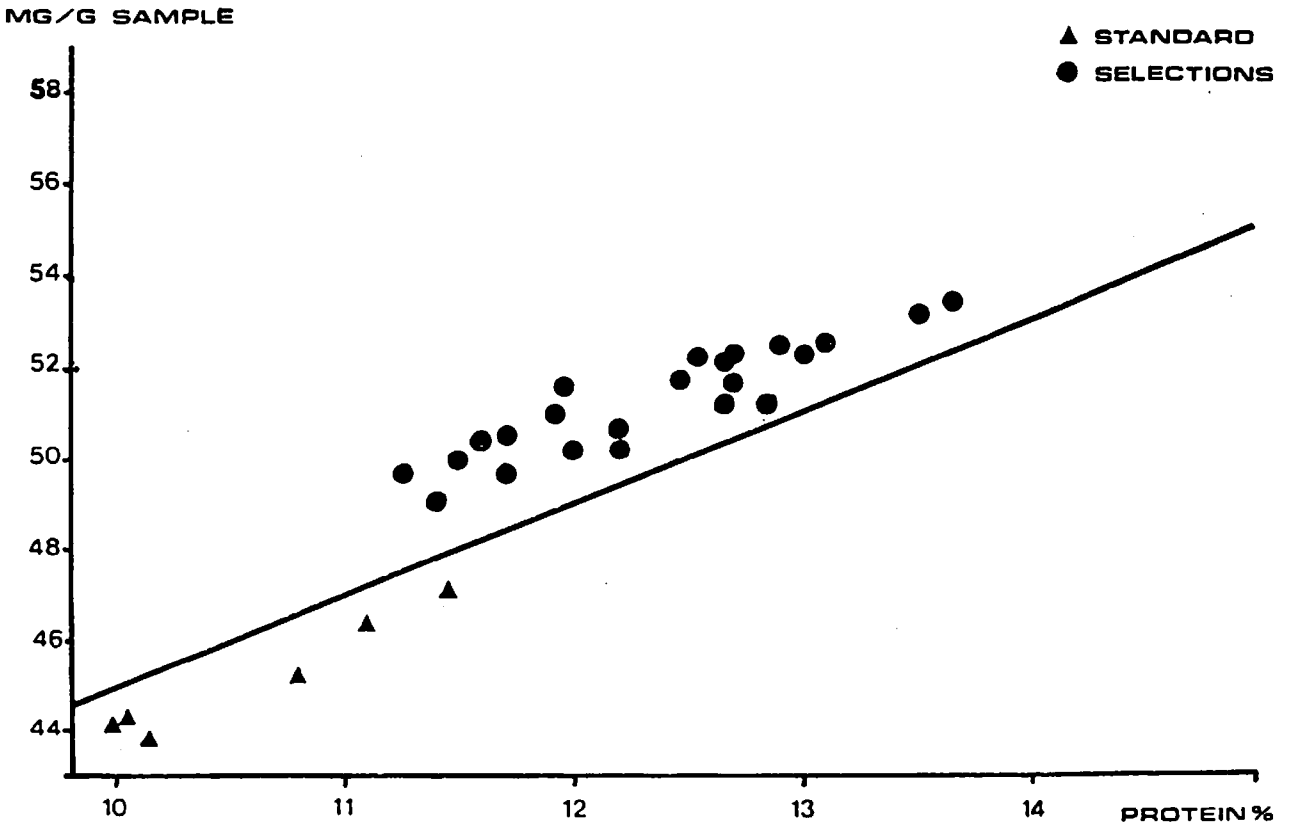

FIG 3 CORRELATION BETWEEN DBC-VALUE AND PROTEIN CONTENT

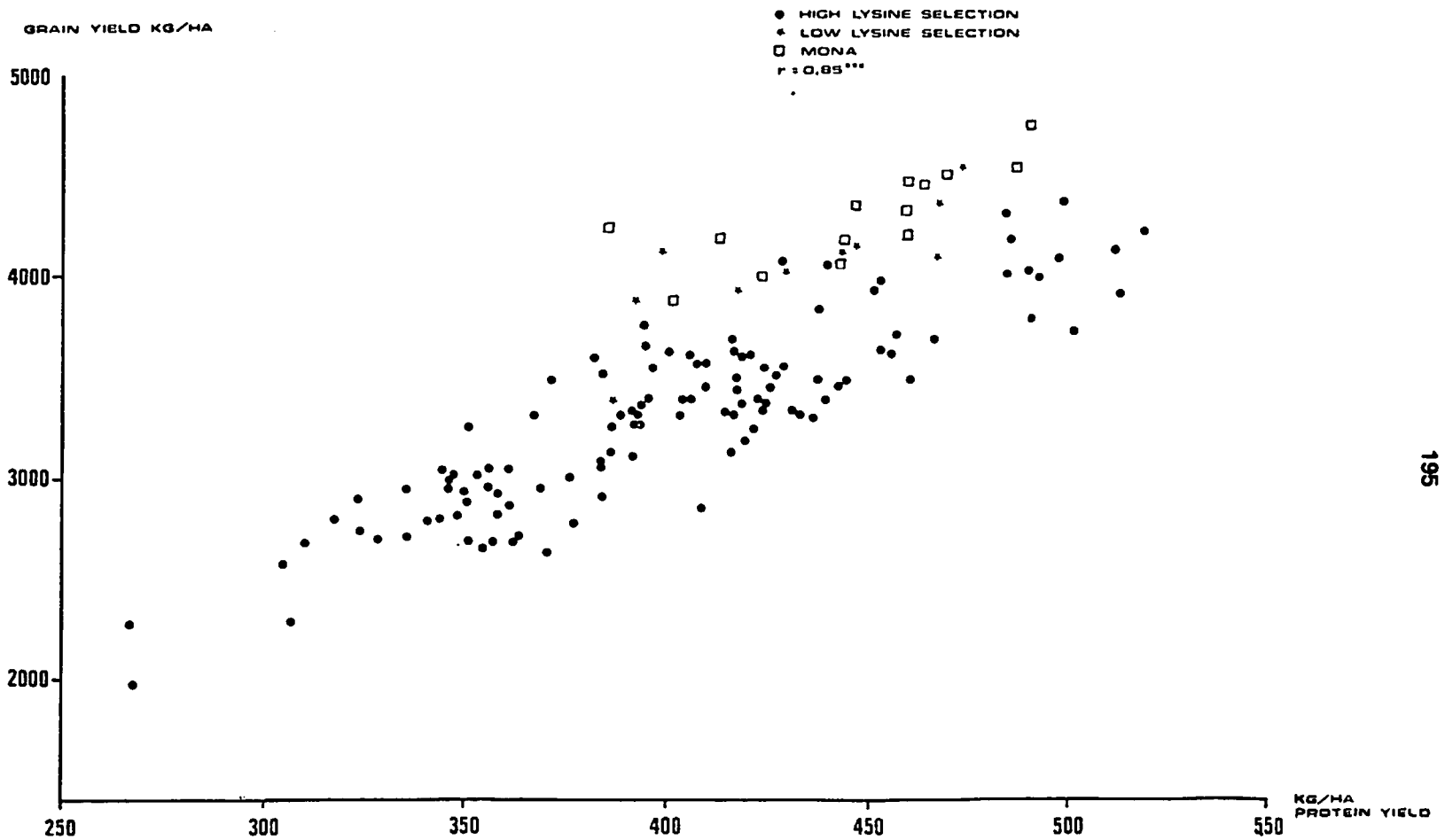

FIG 4 CORRELATION BETWEEN GRAIN YIELD AND PROTEIN YIELD

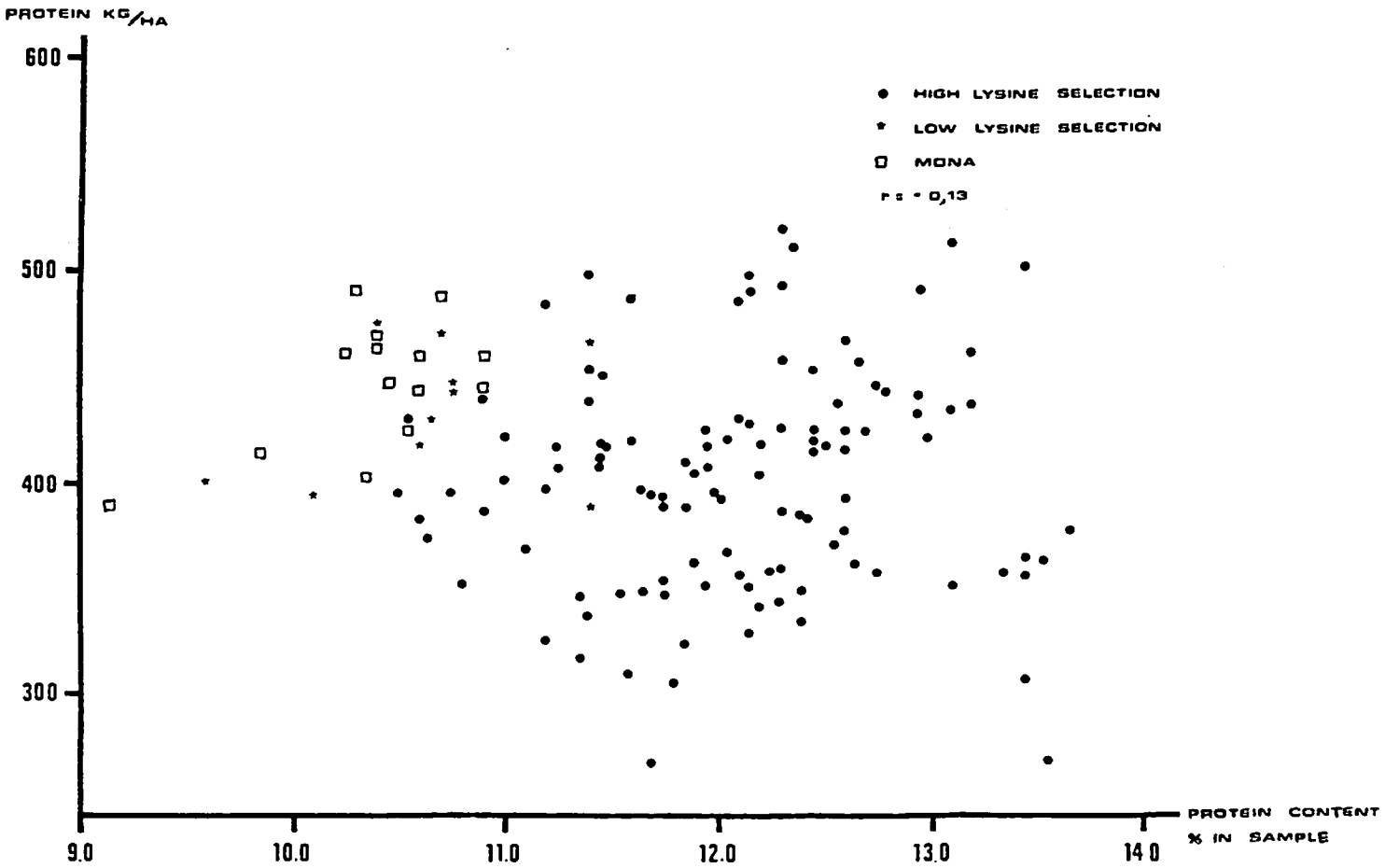

FIG. 5 CORRELATION BETWEEN PROTEIN YIELD AND PROTEIN CONTENT.

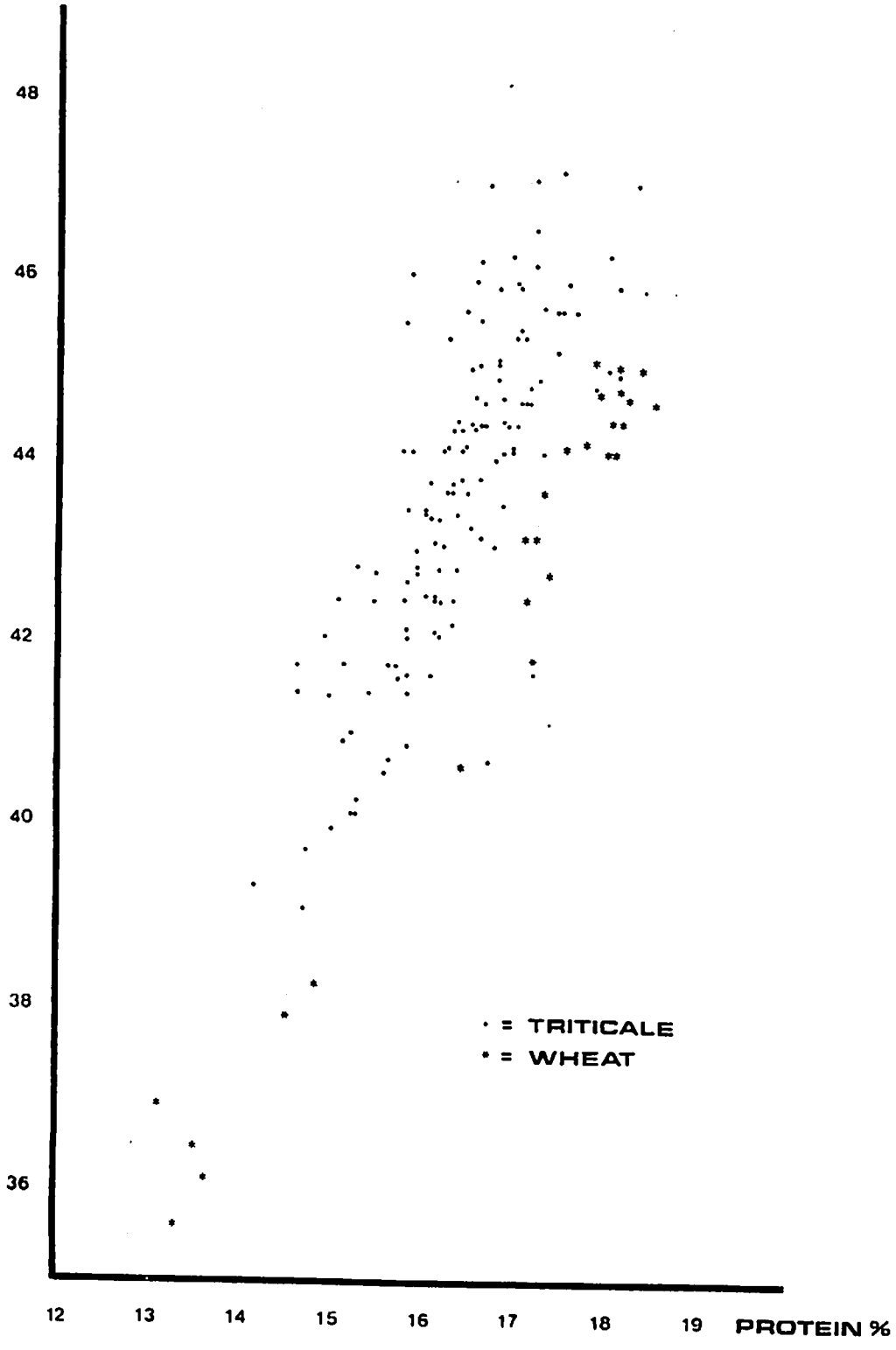

Fig. 6 SPRING TYPES

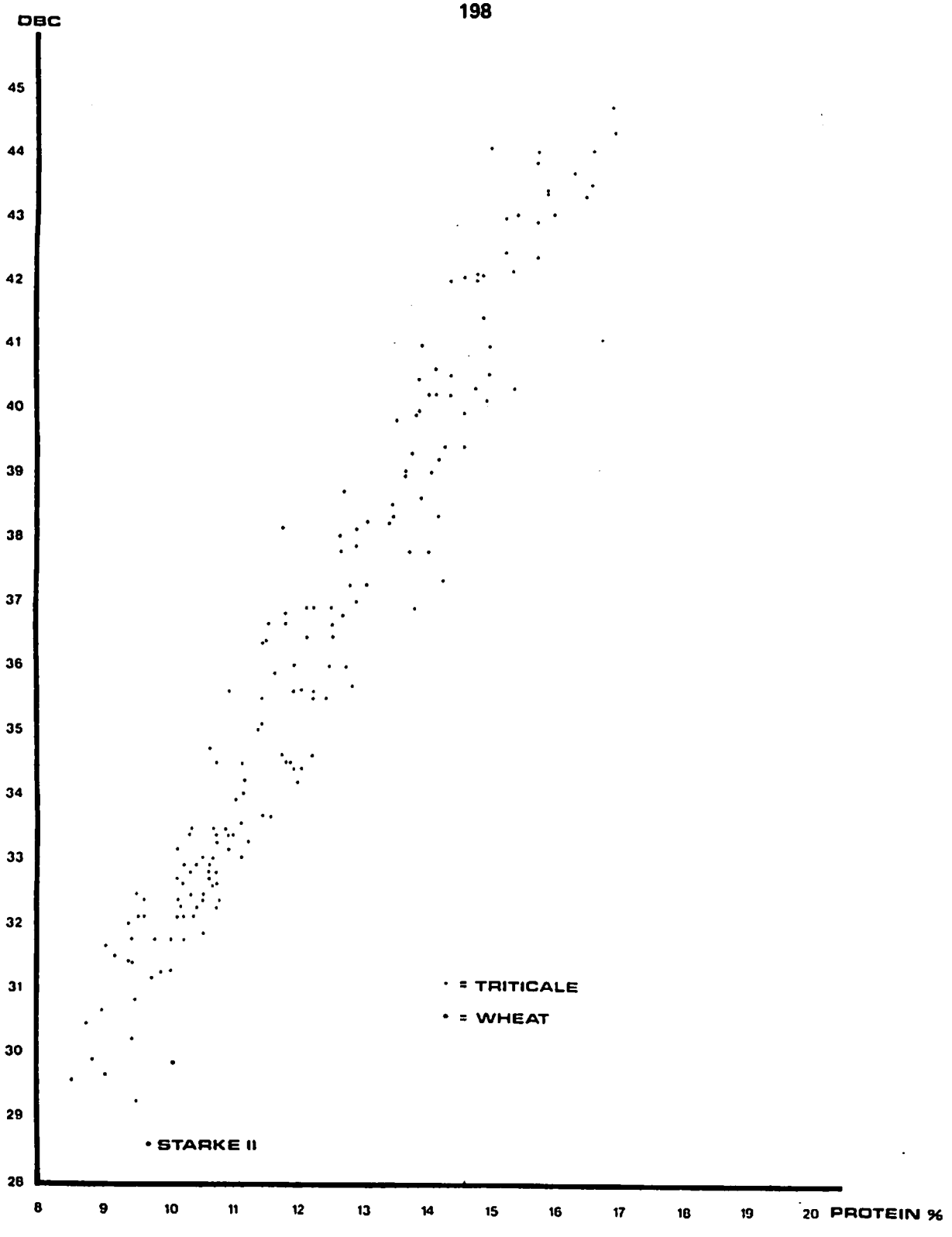

Fig. 7 WINTER TYPES

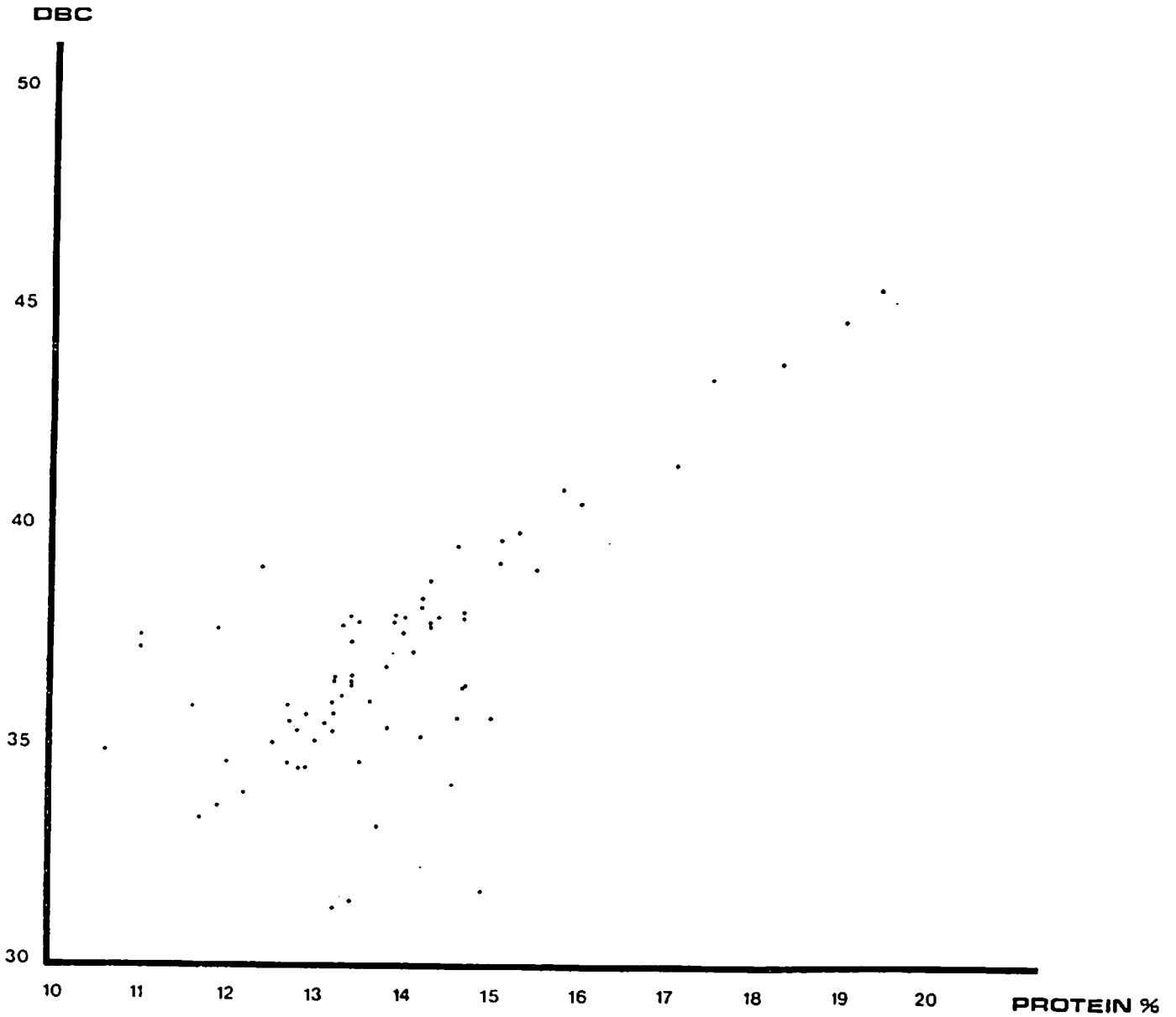

Fig. 8 WINTER RYE SEP. 30 1976

OFF-SEASON WINTER CEREAL NURSERY FACILITIES IN KENYA

By

Gerbrand Kingma*

Barley improvement work in the Middle East and North Africa is usually carried out by the breeders who are responsible for wheat breeding. The overriding importance of wheat in the area has dwarfed the committment given to barley.

In this region cooperative nurseries have been planted in many countries for more than ten years. In 1973 a review of the reports concerning these nurseries lead to the conclusion that these nurseries served as an important source of new germplasm (1).

A Regional Barley Crossing Block was initiated in 1970-71 and distributed to various programs. In this crossing block the best adapted varieties were included along with varieties identified for specific characters. Major groupings included varieties with different sources of disease resistance. Most of the disease data was provided from the Regional Disease and Insect Screening Nurseries (RDISN), which is a widely grown nursery. This program has continued and has been a stimulus to the increased interest and efforts to develop new germplasm.

In order to make fuller use of the results in both wheat and barley the need for an off-season nursery for the Middle East has been felt for sometime. Starting in 1973 breeding materials of breadwheat, durum, barley and triticale have been brought to East Africa from many countries in the Middle East and North Africa. This germplasm is sown at Njoro, Kenya, with the assistance of the Kenya National Program, CIMMYT and ICARDA.

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* CIMMYT/East Africa, P.O.Box 7292, Nakuru, Kenya.

The planting season in East Africa varies greatly, but by planting the nursery by June 15, harvest can take place by late October. These dates fit in with many planting and harvest schedules in the Middle East and North Africa. This effort requires a coordination of effort because of the short time between seasons and the distance involved. The benefits are large because it allows for the advancing of generations of segregating material and provides an additional disease screening for stem and stripe rust and other foliar diseases.

In 1975 a winter barley collection of more than 2,000 entries maintained in Lebanon by the National Program was screened at Njoro, Kenya, which is 2200 m. in elevation. A second planting was done at Mau Narok which is at 3,000 m.

In the field many of the winter barleys did not head out. Scald was particularly severe in Njoro in 1975, while yellow rust was very serious in Mau Narok in 1976. From more than 2,000 lines only 66 were selected for resistance to yellow rust. Sixteen of the lines showed seedling resistance to race 24 in tests conducted by Dr. Stubbs and his colleagues at the institute for Plant Pathology Research (I.P.O.), the Netherlands. (2)

From this group 103 lines of barley were considered resistant to scald in both 1975 and 1976. The selected lines also represented entries which are somewhat early in maturity or daylight insensitive. The lists are too lengthy to include here but this information is available from me or my colleagues upon request. In Table 1 the varieties that were resistant to both yellow rust and scald are listed. These lines were originally received from Dr. J. C. Craddock at USDA in Beltsville, Maryland, U.S.A.

By screening the winter barley group in Kenya it was possible to identify sources of resistance which may not have been used before. A number of these lines have been retained in Kenya for further screening and breeding work. The best will find their way in to yield tests and cooperative nurseries in the region. This type of inter-regional cooperation is facilitating the identification of sources of resistance and the early use of new sources of resistance.

In summary the use of Kenya as a summer nursery satisfies the need to advance breeding material a generation, and the location of Kenya on the equator can help selection for daylight sensitivity if this is required. The severe disease pressure provides an opportunity to select for new sources of resistance in both barley and wheat.

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(1) Aspects of Barley Improvement in the Near East and North Africa - G. Kingma, Arid Lands Agricultural Development Program, the Ford Foundation, Beirut, Lebanon, May 1973.

(2) Barley germplasm screened in Wageningen, the Netherlands, and Njoro, Kenya, J. P. Srivastava and E. E. Saari, Arid Lands Agricultural Development Program, Cairo, Egypt, March 1976.

Table 1.

Barley Varieties Exhibiting Resistance to Yellow Rust (Puccinia striiformis) and Scald (Rhyncosporium secalis) at Njoro and Mau Narok, Kenya, in 1975 and 1976.

Variety	Disease and Score		
	YR Field	YR Seedling*	Scald **
Abyssinian 23	0	R	1.0
Tunis	TMS	S	1.0
CI 13651	5MS	S	1.0
A. Hor 880/61	5MS	S	1.0
CI 11454	TMS	R	1.5

* Data from IPO, The Netherlands

** Average Score of Two Seasons Using 0-9 Scale.

VARIETAL AND GERMPLASM DEVELOPMENT AT WASHINGTON STATE UNIVERSITY

By

R.A.Nilan, A.J.Lejeune and C.E.Muir*

Introduction

This brief report describes the types of barley grown in the State of Washington; types of barley being bred for production in the State and adjacent States; the sources of germplasm being utilized in this program; and the progress in improving various traits in the development of new varieties.

The State of Washington raises about 200,000 hectares of barley. This acreage produces about 435 million kilograms and comprises about 10-15% winter barley and 85-90% spring barley. Barley is grown almost entirely on rainfed land ranging in precipitation from 250 to 700 millimeters. Most of this rainfall occurs in the winter and early spring.

The history of barley improvement in this State very much resembles the evolution of barley production and improvement that is occurring in several countries of Southern Europe, North Africa, and the Middle East. Wheat is the major crop in this State and wheat breeding in Washington has a long history tracing back to original hybrids of Spillman in 1900. Until about 1960 barley improvement consisted of primarily introductions and testing. Since then the breeding work has been intensified with six new varieties released since 1966. Acreage devoted to Washington bred varieties increased from 7% in 1970 to 90% in 1976.

Barley is the major alternate grain crop to wheat. However, in some regions of the State barley is increasing in importance and even being grown more regularly than wheat.

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The State of Washington is unique in that it can produce every type of barley that is grown in the United States and indeed the world. At the present time, the growers in this State are producing 6-row spring feed; 6-row spring malting; 2-row spring malting; and 6-row winter feed.

The Washington State University breeding program has and is developing improved varieties for these different types and is working on the development of 2-row winter and 6-row winter malting types. Also in the feed types, nutritional quality is being improved.

We recognize that at the present, malting types are superior over the so-called feed types for livestock and other animal feed. Thus, our chief overall objective is to reduce the number of types and recommended varieties so that the highest yielding barleys can be utilized for malting, whether spring or winter grown, and also have superior nutritional quality.

Germplasm Sources

The development of various types of barley dictates that our program operate with a broad germplasm base. Our major germplasm sources are: 1) the Coast-type barleys from the North Africa and Middle East region; they have contributed to 6-row spring and winter feed types, 2) 2-row types from Central Europe, and 3) 6-row types from Manchuria. We also utilize germplasm for improving specific traits from the U.S.S.R., Australia, Scandinavia, and the CIMMYT program, from induced mutations and from composite crosses.

The Coast types include old varieties such as Trebi, which originated from the south shore of the Black Sea in Asiatic Turkey; California Mariout, which originally came from Egypt and was grown by Arab farmers along the Mediterranean without irrigation and under eight inches of rainfall; Club Mariout which was from irrigated regions of Egypt; and California Coast, which had its origin in North Africa. These old varieties were introduced into California very early by Spanish colonists. These and other old varieties constitute the basic Coast-type strains which form the primary germplasm base for our program. These types have the best adaptation for barley production west of the Rocky Mountains.

Germplasm for winter barleys of the Coast type had their origins in old varieties as White Winter (Winter Club, Idaho Club).

Washington represents an area in western United States in which Coast-type varieties such as Gem, Atlas, Arrivat, Harlan, and Beecher have grown successfully in past years. These varieties were developed in turn from the original Coast-type introductions from North Africa and the Middle East. It is interesting to note that some of this original germplasm has now been reintroduced to the Mediterranean region in terms of the varieties Atlas, Gem, Beecher and Arrivat. In some North African and Middle East countries these varieties are relatively widely grown and quite successful.

Another major source of germplasm has been the 2-row malting types which had their early origin in Czechoslovakia and Austria and which more recently have come from more Northern European countries such as Scandinavia, England and Germany.

In order to develop acceptable 6-row malting quality, a third important source has been the Manchurian-type barley, which had its origin in Manchuria and came to the U.S. either via Germany or Russia.

It should be noted that transgressive inheritance and many positive "surprises" are being obtained from crosses among the three major types of barley used in this program and between winter and spring strains.

Barley Improvement

The following describes several agronomic, malting and nutritional traits that have been improved in the W.S.U. breeding program.

Winter habit and hardiness

Winterhardiness remains a major problem in the production of winter barley in the Pacific Northwest. An apparent plateau has been reached in hardiness with the variety Hudsón imported from New York and the variety Kamiak which was developed at W.S.U., which contains Coast-type germplasm. Our most recent variety, Boyer, although slightly lower in winterhardiness, does have better yield,

straw strength and kernel size than Kamiak and Hudson. In connection with winter habit and winterhardiness some of our winter sown varieties are facultative (boyer, Luther) and some are true winter varieties (Kamiak) in that they will not head out from spring planting. Extensive work is underway for improving the winterhardiness of the Coast-type germplasm through introductions from the Soviet Union, mutagenesis, and winterhardy composites. Some winterhardiness has been detected in spring selections and varieties that have a Coast-type germplasm. Table 1 shows the yielding ability and winterhardiness of Kamiak, Boyer, Luther and White Winter. The pedigrees of these varieties are presented in Table 2.

Yield

The highest yielding spring variety in the Pacific Northwest states of the U.S.A. is Steptoe, which contains a considerable amount of Coast-type germplasm. Improvements in yield over Steptoe will possibly come through Steptoe x Blazer (our new 6-row malting spring variety). Table 3 shows the yielding ability and other agronomic characteristics of Steptoe, Unitan and Trebi. In addition to yield, Steptoe represents improvement in straw height, strength and maturity. Pedigrees of these varieties are presented in Table 4.

Malting quality

One of the major breakthroughs of the W.S.U. program has been the transfer of acceptable Manchurian-type malting quality into high yielding 6-row Coast-types. The bridge in this development came about with Blazer. This development will be furthered by the new selection WA6591-11312 (Table 5). It approaches the yield of Step-toe and has the quality of Larker, the 6-row malting barley standard in the U.S.A. Its quality is much superior to the Atlas variety which was the original malting barley in the west (Table 6). This selection is in line with the ultimate aim of developing in our highest yielding spring barley genotypes for the Pacific Northwest with excellent malting quality. Such a malting type will also be of great nutritional value than our current feed barleys. Pedigrees of the 6-row spring malting varieties are described in Table 7.

Improvement in the 2-row malting types are represented by Vanguard (Table 8). Higher quality is being obtained from Klages, a new Idaho variety (Table 9). Klages with its high enzyme activity is now the standard 2-row malting barley in the U.S.A. Pedigrees of the 2-row spring malting varieties are described in Table 10.

We are incorporating into 6-row winter barley, with considerable success, the Manchurian-type quality as represented by Larker. Higher enzyme activity for malting is being incorporated into winter 2-row barley through the use of Klages and Southern German 2-row selections. The German 2-row selections possess a fair degree of winterhardiness. Again, as with the spring barley it is anticipated that the highest yielding varieties of winter barley will also meet malting quality standards when grown under appropriate environments.

Straw height and strength

Improvements in straw height and straw stiffness are represented in our new varieties (Tables 1, 3, 5 and 8). These and further improvements will be developed through induced mutants and crosses with short strawed genotypes that have been developed within our program and elsewhere.

Nutritional quality

The high yielding 6-row winter and spring genotypes which contain Coast-type germplasm are being improved in terms of nutritional quality by incorporation of higher lysine. Lysine increase is coming from Hiproly and the induced mutant 1508 out of Bomi. As indicated in Table 11 the yielding ability of some spring naked (A421, A420) and hulled (A412, A418) selections from Steptoe x Hiproly crosses is favorable.

Working with animal nutritionists at our University we are identifying other nutritional characteristics that we must breed into varieties so they will be more useful for livestock feed and possibly human food.

Threshability and Maturity

Our program contains a considerable range of maturity and threshability. Modt of our current varieties and potential new varieties represent vast improvements in terms of threshability and maturity compared to the early Coast-type varieties.

Disease resistance

In the Pacific Northwest diseases are not a problem in barley. This means that very little attention has been paid to disease resistance in our program. However, we are beginning to incorporate Yellow Dwarf and Mildew resistance into some of our lines. We recognize in order for our germplasm and varieties to be of value elsewhere, additional disease resistance is required.

Stress resistance

Resistance to drought and other environmental stresses are considered in our improvement program. Steptoe, for instance, has the ability to yield well under a variety of water levels and indeed, produces reasonable yields when water becomes somewhat limiting. We suspect we have a range of drought resistance in our materials although we have not developed adequate selection techniques to identify such useful variance.

Nitrogen utilization efficiency

We are giving considerable attention to nitrogen utilization and metabolism of barley and attempting to develop lines which utilize nitrogen more efficiently. It appears we may have a fairly wide range of variability for nitrogen utilization efficiency, but again have not had resources to develop the necessary techniques to identify useful germplasm.

Day length sensitivity

We are testing all our genotypes for day length sensitivity and winter habit. We have identified considerable variation in these factors. For instance, Steptoe in the first year test appears to be day light insensitive.

Barley Genetic Literature

The genetics of most barley traits, including those of agronomic and quality value, have been described and summarized in a number of publications. This brief summary is provided for many people in barley breeding who may wish to have more information about the genetics of the traits they are working with.

1. Smith, L., 1951. Cytology and genetics of barley. Botan. Rev. 17: 1-51; 133-202; 285-355. (Available from R.A. Nilan, Department of Agronomy and Soils, Washington State University, Pullman, Washington 99164).

2. Fröier, K., W. Hoffmann, E. Sandegren, and H. Thunaeus, 1959. Gerste (Hordeum vulgare L.) pp. 276-426. Handbuch der Pflanzenzüchtung. II. 2nd edition, Paul Parey. Berlin.

3. U. S. Department of Agriculture, 1968. Barley: Origin, botany, culture, winterhardiness, genetics, utilization, pests. Agriculture Handbook No. 338, Agricultural Research Service, Washington, D.C. 127 pp.

4. Nilan, R. A., 1964. The Cytology and Genetics of Barley, 1951-1962. Washington State University Press, Pullman, Washington. 278 pp. (Available from the Washington State University Press, Pullman, Washington 99164, $4.00).

5. Nilan, R. A., 1974. Barley (Hordeum vulgare). In: Handbook of Genetics, Vol. 2: Plants, Plant Viruses, and Protists. Chapter 4, pp. 93-100. Robert C. King, ed. Plenum Press, New York. (Reprints available from R. A. Nilan).

6. Lamberts, H., 1964. Barley Genetics I. Proceedings of the First International Barley Genetics Symposium, Wageningen, 1963. Pudoc, Center for Agricultural Publications and Documentation, Wageningen, The Netherlands. 387 pp. (Available from Pudoc, Wageningen).

7. Nilan, R.A. (ed.), 1971. Barley Genetics II. Proceedings of the Second International Barley Genetics Symposium, Pullman, 1969. Washington State University Press, Pullman, Washington. 622 pp. (Available from Washington State University Press, Pullman, Washington 99164, $20.00).

8. Gaul, H. (ed.), 1976. Barley Genetics III. Proceedings of the Third International Barley Genetics Symposium, Garching, 1975. Verlag Karl Thiemig, Munich, FRG. 849 pp. (Available from Verlag Karl Thiemig, Postfach 90 07 40, D-8000 München 90, Federal Republic of Germany, DM 130).

Two Newsletters which annually publish articles of interest to barley breeders:

1. Barley Genetics Newsletter. Vol. 7, 1977. Copies of this and previous editions can be obtained from Dr. T. Tsuchiya, Department of Agronomy, Colorado State University, Fort Collins, Colorado 80523, $5.00 per volume.

2. Barley Newsletter. Vol. 20, 1977. Copies may be obtained from the editor, Dr. R. G. Timian, Department of Plant Pathology, North Dakota State University, Fargo, North Dakota 58102.

TABLE 1

AGRONOMIC DATA OF WINTER 6-ROW*

	HT cm	HEADED	WINT SURV %	LOD %	PLUMP % 6/64	HL WT kg	YIELD kg/ha
KAMIAK	109	5-19	100	13	75	66.8	6861
BOYER	96	5-26	100	3	73	64.0	7001
LUTHER	104	6-10	98	17	53	62.9	6005
WHITE WINTER	119	6-9	94	32	87	63.5	4738

*PULLMAN, WASHINGTON, 1971-76

TABLE 2

PEDIGREES OF WSU WINTER VARIETIES

BOYER (WSU)

Luther x WA1255-60
Luther = Mutant from Alpine
WA1255-60 = Rufflyn x White Winter

KAMIAK (WSU)

Bore x Hudson
Bore = Introduction from Sweden
Hudson = Michigan Winter x Wong

LUTHER (WSU)

Induced Mutation from Alpine
Alpine = Colo. 3063 (Coast x lion)xWhite Winter

WHITE WINTER

Origin Unknown, Probably
Introduced to Utah
from California

TABLE 3

AGRONOMIC DATA OF SPRING FEED 6-ROW*

	HT cm	HEADED DAYS FROM 1-1	LOD %	PLUMP % 6/64	HL WT kg	YIELD kg/ha
STEPTOE	77.5	165.9	15.8	89.2	62.3	5235
UNITAN	86.1	166.8	31.5	79.2	62.3	4295
TREBI	79.0	171.2	48.6	80.2	60.9	4153

*1970-1976 144 STATION-YEARS, USDA WESTERN REGIONAL NURSERIES

TABLE 4

PEDIGREES OF SPRING 6-ROW FEED VARIETIES

STEPTOE (WSU)

WA3564 x Unitan
WA3564 = Sel. from C.C. IV
Unitan = Glacier x Titan

UNITAN (Montana)

Glacier x Titan
Glacier = Atlas x Vaughn
Titan = Trebi x Glabron

TREBI

Selected from Bulk Seed
Intoduced from the South
Shore of the Black Sea Via
Trebizond, Asiatic Turkey

TABLE 5

AGRONOMIC DATA OF SPRING MALTING 6-ROW*

	HT cm	HEADED	LOD %	PLUMP % 6/64	HL WT kg	YIELD kg/ha
11312	83.1	6-18	tr	72	63.2	5187
BLAZER	99.8	6-25	0	74	65.4	4816
LARKER	103.4	6-22	9.3	93	66.7	4181

*WASHINGTON STATE, 1975-76

TABLE 6

QUALITY DATA OF SPRING (6-ROW) MALTING*

	MALT EXT %	MALT EXT F-C	TOT PRO %	SOL PRO %	SOL/ TOT PRO	DP oL	ALPHA AMY 20°DU	DP/ PRO	VISCO 1976
11312	77.7	1.9	11.1	4.24	38.2	173	50.2	15.6	1.47
BLAZER	77.5	2.0	11.6	4.43	38.2	118	49.0	10.2	1.49
LARKER	77.0	1.4	13.2	5.04	38.2	187	49.0	14.2	1.44
ATLAS**	71.1	3.0	13.4	4.04	31.9	101	31.4	7.5	--

*WASHINGTON, 1974-76, 2 LOCATIONS

**CALCULATED FROM OTHER COMPARISONS WITH LARKER

TABLE 7

PEDIGREES OF 6-ROW SPRING MALTING VARIETIES AND SELECTIONS

WA11312-73 (WSU)

WA6194-63 x Blazer
WA6194-63 = (Foma x Triple Bearded Mariout)xWhite Winter
Blazer = Traill x WA1038

BLAZER (WSU)

Traill x WA1038
Traill = Kindred x Titan
WA1038 = Induced Mutant from Or. Lemma x Gem
Gem = Atlas x Vaughn

LARKER

Traill x Univ. of Manitoba 570
Traill = Kindred x Titan
U.M. 570 = (Peatland x Newal) x Montcalm

ATLAS

Selection from Coast
Introduced by Spanish Settlers

TABLE 8

AGRONOMIC DATA OF SPRING 2-ROW*

	HT cm	HEADED	LOD %	PLUMP % 6/64	HL WT kg	YIELD kg/ha
VANGUARD	89	6-26	8	85	70.0	4643
KLAGES	89	6-30	9	85	68.9	4111
HANNA	94	6-25	29	88	69.0	3661

*PULLMAN, WASHINGTON, 1971-76

TABLE 9

QUALITY DATA OF SPRING 2-ROW*

	MALT EXT %	MALT F-C DIF	PRO %	SOL PRO %	SOL/ TOT PRO	DP °L	ALPHA AMY 20°DU	DP/ PRO
VANGUARD	78.6	4.3	12.7	3.84	31.4	149	34.9	11.7
KLAGES	80.3	2.9	13.0	4.92	39.2	171	47.1	13.2
HANNA	77.4	5.2	13.5	4.11	31.8	158	31.9	11.7

*WESTERN TWO-ROW NURSERY, 1971 (10 stations)

TABLE 10

PEDIGREES OF 2-ROW SPRING MALTING VARIETIES

VANGUARD (WSU)

Betzes x Haisa II x Piroline
All Introduced from Europe

KLAGES (Idaho)

Betzes x Domen
Betzes = Introduced Via Poland
Domen = Opal B x Maskin, Norway

HANNA

Introduced from Moravia, Austria

TABLE 11

HIGH LYSINE SELECTIONS FROM HIPROLY

	HULL	TOT PRO %	LYS mg PER 100 mg PRO	PLUMP % 6/64	1000 kw gms	YIELD kg/ha	TOT PRO kg/ha	LYS kg/ha
STEPTOE	+	10.2	3.7	94	48.7	4407	449.5	16.63
A412	+	16.5	4.4	30	31.1	3344	551.8	24.28
A418	+	14.4	4.3	52	35.4	3073	442.5	19.03
A421	-	16.8	4.1	5	25.5	2588	434.8	17.83
A428	-	15.4	4.4	7	26.4	3105	478.2	21.04
HIPROLY	-	17.2	4.3	3	40.6	1146	197.1	8.48

AGRONOMY AND PRODUCTION

AGRO-CLIMATOLOGICAL ENVIRONMENTS AND BARLEY PRODUCTION

by

Piero Bronzi*

The improvement of barley production pre-supposes a clear understanding of the farming system in which this crop is grown, as well as of the factors that determine its location and intensity. These factors can be classified in three broad categories: socio-economic, structural-institutional and agro-meteorological.

In the past, a considerable part of barley production in the Middle East and in the Mediterranean regions was used for human consumption. Over the years, the conditions of life, the habits and tastes of the barley-consuming population evolved rapidly. Instead of a primitive barley meal, these people began to prefer the home-made, flat bread made from durum wheat; and now with the urbanization process and the spread of the market economy to most of the remote areas, people have become used, wherever possible, to buying fresh bread daily.

This evolution, coupled with the effectsof the population increase experienced by North African and Middle Eastern countries in the last decades, is in my opinion a main determinant of the present state of barley production, currently characterized as follows:

i. Barley has become essentially an animal feed.(1)

ii. Barley is traditionally considered a poor man's crop, not worthy of research attention or of a share of the meager research capacity available within the countries of the region.

iii. Wheat has been extended over areas where barley has definite comparative advantages.

iv. Barley is now generally sown, from an agro-meteorological point of view, on marginal lands.

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* The Ford Foundation, P.O.Box 2344, Cairo, Egypt.

(1) Barley for malt is considered in this paper as an industrial crop, and is therefore not taken into consideration.

If one observes the distribution of winter cereals in the countries of the North African and Middle Eastern regions, he will conclude that the best and better rainfed lands are cropped with bread wheat; the most arid lands, often on the fringe of the steppe, are cropped with barley; and durum wheat, grown essentially for home consumption, occupies an intermediate position and area.

Agro-climatological factors

There are two precise reasons for giving adequate attention to the agro-climatological conditions in which barley production takes place. The first is that most of the agro-climatological factors are determined by nature and therefore are "given". Through a series of agronomic "influents", man tries to modify and smooth the impact of these relative fixed factors on the production process; however, the spectrum of real possibilities at his disposal is limited by economic considerations and by the degree of risk that the farmer is able or willing to bear.

The second reason is represented by the fact that, through a better understanding of the agro-climatological factors influencing the physiology and the production of winter cereals a more rational redistribution of the area traditionally cropped with barley, durum and bread wheat may be achieved. As Saari and Srivastava (1977) point out, barley in terms of production uses more efficiently than wheat the water available to the plant up to 450 mm of rainfall or irrigation per year.

In most of the Middle Eastern and North African regions barley is grown under rainfed,(1) semi-arid conditions.(2) But

(1) "Rainfed" is used hereafter as a synonym of "dry-land"; both terms presuppose the condition of not being irrigated.

(2) "Semi-arid" is used hereafter for climatic situations in which rainfall is, on the average, sufficient to sustain a winter crop production. Where rainfall is not sufficient, the climate is defined as "arid". Shifting cultivations of barley are found also in the arid zone, but only during those years when enough rain has fallen in the late fall and then only in the wadis where water accumulates.

from the point of view of agricultural production, the concept of rainfed semi-arid conditions as defined in the footnotes is not precise enough and must be qualified further in order to give operational indications. Even if we take into consideration, as in this paper, only those rainfed semi-arid situations where the hydrological growing season coincides with the colder months of the year, as in the Middle East, Mediterranean and South Australia regions.(1) we find an array of agro-meteorological environments, each presenting specific characteristics and therefore requiring different production patterns, technologies and practices.

Characterization of Different Rainfed, Semi-Arid Environments.(2)

Within the Mediterranean and Middle East regions there are three distinct types of agro-meteorological environments: the Mediterranean, the semi-arid Mediterranean (Fertile Crescent) and the Continental (Iranian and Anatolian high plateaux). Deficiencies in soil moisture represent to a different degree the major constraint for the development of agricultural production in all three environments; temperature represents a second major constraint in the continental environment.

The study of the influence of the agro-meteorological factors upon agricultural production cannot be carried out by taking into consideration only individual factors, but must focus on the interaction of these factors among themselves. These interactions are seldom quantifiable. Attempts to measure them have been made, but the results are either too theoretical or too location-specific.

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(1) These regions have a climate which is broadly defined as Mediterranean.

(2) This section is based on informations and data of 143 meteorological stations in Algeria, Jordan, Syria, South Australia and Tunisia. Tables and graphs are included in Agro-Climatological Constraints to Improving Dry-Land Production Technology, by P.Bronzi. This paper was presented at the Middle East and Africa Agricultural Seminar organized by The Ford Foundation in Tunis, Tunisia, February 1-3, 1977.

However, given our present level of knowledge, evapotranspiration (ETP) is the best available method of studying the complex reality of these interactions. The Penman method of computing ETP seems the most appropriate for the Mediterranean and Fertile Crescent regions and for the season during which winter crops are cultivated.

The success or failure, both in absolute and in relative terms, of agricultural production is intimately connected to the timely implementation of given agronomic practices, under the control of man, as well as to the occurrence or absence of given climatic events, outside the control of man. A high degree of monthly, seasonal or annual variation in some important factors introduces a high degree of uncertainty that in the ultimate analysis has a bearing on the economic behavior of farmers, the level of intensity of their farming and their propensity to adopt new capital intensive technologies.

From the evidence gathered up to present, it seems that the Mediterranean environment presents a lower level of rainfall variation than does the Fertile Crescent, even where the amount of rainfall is comparable. The explanation should be sought in the general circulation of the atmosphere of these two regions, as well as in the "barrier effect" determined by the mountains stretching along the western shores of the Mediterranean area.

The use of monthly average data, although indicative in a preliminary approach to the problem, can have misleading effects if not properly interpreted in the analysis of the climate for agricultural purposes. Moreover, the interval of monthly data is too long and can mask the occurrence or not of events which may have important consequences on plants and production. Ten days' data seems perfectly suited for this type of analysis.

Important indications, both of a descriptive and of an operational nature, can be derived only by the frequential treatment of determined climatic parameters. The application of Franquin's (1968) methodology to the concrete cases of Amman, Irbid and Madaba in Jordan has given good results. Only precipitation and ETP parameters were used, but the model is flexible enough to take into account other parameters such as temperature, late frosts, early sciroccos.

However, even the frequential analysis of climatological events can be a futile exercise if the interactions between these events and agronomic factors, especially soil, are not considered. Franquin's ORBVCP program allows for the inclusion of soil parameters in the calculation of water balances for every 10 days and for each hydrological season. The 35 water balances made for Amman Airport, from 1939-40 to 1973-74, show that precipitation was never able to fill the water holding capacity of the soil and that deep drainage never took place.

The frequential analysis of the situations in Irbid, Madaba and Amman, the latter more than the former, shows that moisture is the most important constraint for the development of the presently applied level of technology. The high level of monthly, seasonal and annual rainfall variability, the shortness of the wet season, the probabilities of an intra-seasonal drought strongly indicate that the stabilization and the sizeable improvement of production will be achieved only by increasing the amount of moisture available to the plant and by extending the duration of the wet period.

Soil Considerations

Middle Eastern and in particular Jordanian soils are heavy, rich in clay and consequently relatively impermeable. The slope of these soils is important, a factor that further reduces the penetration of the water, especially when the intensity of precipitation is important, as we saw in the case of Amman.

Water run-off, although difficult to quantify, is important. The erosion determined by this run-off, and aggravated by the recent indiscriminate mechanization of soil preparation in all the different agro-meteorological situations, further contributes to a permanent deterioration of the environment.

All soil conservation[1] and agronomic practices which are aimed at improving the soil permeability to water, reducing run-off and preventing soil erosion, are instrumental in stabilizing and improving not only barley but total agricultural production. In this

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(1) As those implemented in Jordan by the Ministry of Agriculture with the assistance of the World Food Program and the FAO program in Irbid.

context, the control of weeds which compete with winter cereals for the use of available soil moisture is of capital importance, especially in the dry situations where barley is grown. For example, the IDGC[1] Algeria has demonstrated that the national winter cereal production is reduced by at least 30 percent by the presence of weeds in the fields.

The water balances referred to in the previous paragraphs were made under the unrealistic hypothesis that precipitation was completely absorbed by the soil and that no run-off took place. Precise data on run-off do not exist, in Jordan or elsewhere. The only solution to offset this inconvenience would be to correlate actual soil moisture measurements with actual precipitation for ten-day periods over a number of years. Unfortunately, sufficiently long series of soil moisture measurements are not available in the 143 stations taken into account in this paper.

Barley

Empirical evidence shows that barley is better adapted than wheat to the environmental conditions where moisture, especially in the spring, is a limiting factor for the normal development of the cereal plant. This can be explained by some physiological features that differentiate barley from wheat plants, such as the amount of cutin on the leaves, which forms a continuous insoluble and impermeable layer on the outer epidermal walls of the plant; the particular architecture of the stomata and the sub-stomata cavities which determine the path length for gaseous diffusion and control the intensity of both CO_2 and water vapor exchanges as well as the plant metabolism (Slatyer 1967); the degree of salt tolerance that gives the plant the capacity to extract more water from the soil; the particular root system which is reportedly more developed. The superior adaptation of barley can also be explained by the different "earliness" of barley and wheat. It is amply demonstrated that sufficient moisture in the flowering and milk stages of the plant is one of the most important determinants of the yield levels. The flowering and reproductive stages of barley in Jordan, Tunisia and Algeria take place 10-15 days before those of wheat.

With the present level of knowledge it is impossible to determine precisely the moisture threshold below which barley has

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(1) Institute de Development des Grandes Cultures, Alger.

definite comparative advantages over wheat. From an agro-climatological point of view, empirical evidence indicates that this threshold is situated at 450 mm of mean annual rainfall. However, socio-economic and institutional factors affecting the farming systems of the Middle East and North Africa regions should be considered before advising farmers to depart from the cropping patterns implemented at present. In fact, for the large majority of farmers, these cropping patterns are determined by home-consumption rather than market considerations.

It is also impossible to determine with precision the lower rainfall limit below which no barley or other winter cereal should be grown. As a result of the ever increasing population pressure on land and the spread of agricultural mechanization much land receiving less than an average of 250-300 mm. of rainfall/year is actually cultivated. The productivity of these crops is very low whereas the negative, irreversible consequences of land preparation practices on the environment are very serious. Clear evidence of this problem emerged at the Pastoralism Conference held in 1973 in Algeria, and emerges from the results of the bio-mass and desertification researches being carried out in Tunisia and Egypt, while the Syrian legislation preventing crops below the 300 mm isohyet represents a concrete attempt to solve the problem.

1) Shehadeh, No'man - Variability of Rainfall in Jordan, University of Jordan, no date.

2) Perrin de Brichambeaut, G. and Wallin, C.C., A Study of Agroclimatology in Semi-Arid and Arid Zones of the Near East, FAO, Rome 1962.

3) Palataef, N., - Action du Travail Profond du Sol sur sa Fertilite et sur les Rendements des Cereales, Annales du S.B.A.T. Volume 26, Tunis, 1953.

4) Yankovitch, L., Resultats de 22 Annees d'Experiences dans les Cases Lysimetriques et Cases de Vegetation du Service Botanique et Agronomique de Tunisie, Annales du S.B.A.T., Volume 29, Tunis, 1956.

5) Arnon, I., Crop Production in Dry Regions, Volume I, Leonard Hill, London, 1972.

6) Duwayri, M., and Saket, I., Review of Twenty Five Years of Soil Fertility Research on Wheat in Jordan, University of Jordan, 1976.

7) Franquin, P. Analyse Agroclimatique en Regions Tropicales: Methods des Intersections et Periode Frequentielle de Vegetation, O.R.S.T.O.M. Paris, no date.

8) Franquin, P., Analyse Agronomatique en Regions Tropicales: Saison Pluvieuse et Saison Humide. Applications. Cah. O.R.S.T.O.M. Ser. Biol. No.9, 1968.

9) Hopkinson, D., Technical Report on the Development of Crop Husbandry in the Dryland Farming Areas Around Karak, WSH 7216, FAO Rome, 1975.

10) El-Hurani, M.H., Economic Analysis of the Development of the Wheat Sector of Jordan, Ph.D.Thesis, Iowa State University, 1975.

11) Bronzi, P., Agroclimatological Constraints to Improving Dryland Production Technology, Middle East and Africa Agricultural Seminar, The Ford Foundation, Tunis, Tunisia, February 1-3, 1977.

12) Saari, E.E., and Srivastava, J.P., Improvement and Stabilization of Production of the Winter Cereals: Potentials in a Single-Crop System, Middle East and Africa Agricultural Seminar, The Ford Foundation, Tunis, Tunisia, February 1-3, 1977.

13) Slatyer, R.O., Plant Water Relationships, Academic Press - London and New York, 1967,

THE AGRONOMIC UNIQUENESS OF BARLEY

Bill C. Wright*

If barley is not truly unique, agronomically speaking, it does have several distinct characteristics which allow it to grow in places where other winter cereals cannot. It does have one unique characteristic, however, which has helped barley to maintain its place in the world -- its malting qualities.

Early Maturity

Perhaps the most important characteristic of barley that enables this crop to grow where others cannot is its short maturity period. Varieties of barley exist that can mature in 65-70 days. Barley's earliness permits it to grow at high elevations and in Northern latitudes where the growing season is too short for other cereals. On a global basis barley is distributed much the same as wheat except that barley extends farther north in Europe and farther into the arid areas of North Africa, the Middle East; and America. The great high plateau of Tibet and part of China is a region where barley is the only cereal that can be grown; similarly, barley is grown in the high plateaus of Peru, Bolivia, and South Africa.

Barley's early maturity also allows it to grow in other areas quite different from those just described. Because it is early maturing, barley can escape the hot, dry period in several semi-arid regions of the world, especially in the winter rainfall regions of the Mediterranean and Western United States. In these areas of low, variable rainfall barley usually can grow and set seed before the rainy period ends and before the hot, dry weather, sets in with a vengeance. The prominence of barley in nearly all the countries of North Africa and the Middle East attests to barley's adaptability in such situations.

The short maturity period of barley is valuable in yet another agronomic situation. In multiple cropping patterns barley can often fit in where its chief rival, wheat, cannot. Barley-rice cropping sequences are particularly important in Korea and parts of China. In Korea barley can be harvested in time to prepare the land and plant rice whereas wheat, even though only a couple of weeks later, delays the rice planting often causing serious yield reductions. In the Aegean area of Turkey barley has recently become relatively more important because of its

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early maturity and its usefulness in multiple cropping patterns. I predict that in the future the area of barley will rise in areas where multiple cropping is feasible (and, of course, where barley is adapted). It is worthwhile to note that early maturity often allows barley to escape diseases, especially rusts.

Tolerance to Soil Salinity

A second important characteristic of barley is its tolerance to soil salinity. Salt tolerance, coupled with a short maturity period, makes barley the only cereal which can grow successfully in many parts of North Africa and the Middle East. In areas of low rainfall salt often accumulates in the lower-lying soils, usually the best agricultural soils. In much of the Middle East and North Africa temperatures shoot up in the early spring often accompanied by hot, dry winds that will wither an immature crop. In this situation barley alone of all the cereals can produce grain.

This tolerance to salt is well documented in the scientific literature. For example A.D. Ayers when he was at the Salinity Laboratory in Riverside, California, showed that barley seed will germinate at high salt concentrations. More than 50% of the seed of a salt-tolerant variety germinated and emerged from a soil in which the osmotic pressure of the soil solution was more than 19 atmospheres (2). Ayers and his co-workers also showed that barley is tolerant to salt at all stages of growth especially at the germination, the stem elongation, and the reproductive phases (1). These studies showed that a tolerant variety could produce grain satisfactorily even though irrigated with water containing 20,000 ppm of salt (about 60% the salt content of sea-water), providing that the salinity level was relatively low during seedling development. Of the 70 crops tested, barley had the highest salt tolerance. More recently Rush and others (5) produced a barley crop of 1190 kg/ha grown on dune sand and irrigated with sea-water. This yield is about one-fifth of the average irrigated barley field in California

Crown Root Depth

Barley may have a third advantage over wheat. I say "may" because my argument is based on somewhat casual observations by Bert Krantz and me. It appears that barley, or at least some varieties of barley, set the crown node and hence the secondary root system at a deeper depth in the soil than does wheat. This is a very important point. If the soil is dry at the crown node level, the crown roots will initiate but they will not develop until the soil becomes wet. If the crown roots do not develop, the entire plant must be supported by the primary root system which simply does not have the capacity to support a vigorous, high-yielding plant.

In India I have observed that some barley varieties, when planted 6-7 cm deep, set the crown node only 1-2 cm above the seed. This is unlike wheat which generally sets the crown just below the surface regardless of its planting depth. B.A. Krantz also made this same observation in India. In a demonstration plot in an Indian village he noted that the barley variety Ratna was growing vigorously while the wheat variety Kalyansona, planted on the same day with the same equipment, was poor. When he dug up the plants, he found the barley crown roots were set at about 5 cm depth in moist soil while the wheat crown roots were only about 2 cm deep in dry soil. Under these conditions the wheat roots failed to elongate but the barley roots developed normally and were able to utilize the moisture in the soil profile.

Dr. Krantz followed this up by randomly selecting a large number of wheat and barley plants from experimental plots in Delhi. The findings revealed that the average depth of the crown roots of barley was 4.5 cm but only 2.2 for wheat (3). I must caution that these are very limited observations. It is important, I think, that systematic experiments be conducted to verify or refute these observations. In my opinion ICARDA would certainly want to explore this subject thoroughly.

Moisture Use Efficiency

Perhaps barley may have yet another advantage over wheat. Data collected by Saari and Srivastava from this region suggest that barley utilizes water more efficiently than wheat at low moisture levels (4). Conversely wheat appears to be more efficient at higher moisture levels. They averaged the yield of all entries in the Rainfed Wheat Yield Trial (12 locations) and the Regional Barley Yield Trial for 1975-76 and calculated the kilograms of grain produced per mm of moisture. The results are given in the following table.

Moisture (rainfall or irrigation)	Kg grain / mm moisture	
	Barley	Wheat
200	7.5	1.1
300	8.0	6.1
400	8.7	5.6
500	3.4	8.7
600	5.6	7.8
700	4.7	11.6

From these data it appears that barley may be more efficient below about 400 mm while wheat is more efficient above 400 mm of moisture. In contrast to these data, similar calculations from 40 yield trials in Turkey indicate that barley is always more efficient than wheat; however, nearly all the Turkish data were collected under less than 450 mm rainfall which would fit with Saari and Srivastava's data.

Disadvantages of Barley

Around the world barley is grown in areas of low rainfall. The only areas of high rainfall growing barley are those areas where the season is too short for other cerals, for example Northern Europe, or areas where barley for malting is the primary consideration. Why is that so? I believe the principal reasons are that barley, as a crop, is very seriously attacked by diseases and it has a pronounced tendency to lodge. Under high rainfall conditions barley is decimated by diseases and it lodges, thus seriously reducing its yield potential. Since both these faults can be corrected through plant breeding, it is likely that barley may extend its range of adaptability in the future.

Another problem limiting barley's adaptation is its sensitivity to soil aluminum. As the soil pH descreases, soil aluminum becomes more soluble and can become toxic to sensititve species. Barley has the reputation of being especially sensitive to soil aluminum but there is a great deal of variability within the barley germplasm in this regard. Even though the largest part of barley germplasm appears to be susceptible to aluminum toxicity, there are lines and varieties which have acceptable tolerance. In this respect barley is similar to wheat. Since the genetic variation exists, plant breeders have the opportunity to develop aluminum-tolerant varieties thereby extending barley s range of adaptation.

Summary

In summary, barley has several agronomic characteristics which enable it to grow well in certain areas relative to other winter cereals:

1) Barley is early maturing thus permiting it to grow at higher elevations and more northerly latitudes than wheat.

2) Barley's early maturity allows it to grow in drier areas where hot, dry weather in the spring often causes wheat to fail.

3) Early maturing barley fits into many multiple cropping sequences where the later maturing wheat will not .

4) Barley has pronounced tolerance to soil salinity.

5) Some barley varieties may set the crown node deeper in the soil than wheat, thus giving it an advantage in low rainfall conditions. This point needs to be studied thoroughly.

6) There are indications that barley may be more efficient than wheat in using moisture in low moisture regimes. This point also needs further study.

REFERENCES

1) Ayers, A.D., J.M. Brown, and C.H. Wadleigh. 1952. Salt Tolerance of Barley and Wheat in Soil Plots Receiving Several Salinization Regimes. Agron. J., 44:407-310.

2) Ayers, A.D., 1953. Germination and Emergence of Several Varieties of Barley in Salinized Soil. Agron. J., 45:68-71.

3) Krantz, B.A. 1977. Personal communication.

4) Saari, E.E. and Srivastava, J.P. 1977. Improvement and Stabilization of Production of the Winter Cerals: Potentials in a Single-Crop System. Paper prepared for a Ford Foundation Seminar, February 1-3, 1977 Tunis, Tunisia.

5) Rush, D.W., J.D. Norlyn, and Emanuel Epstein,1976. Salt Resistant Crops Coming. Crops and Soils Magazine. 29(3):7-9.

ASPECTS OF IMPROVING AGRONOMIC PRACTICES TO MAXIMIZE BARLEY YIELDS IN THE REGION

By

A. Hadjichristodoulou*

Barley is an old crop in the Near East, North Africa, and some Asian countries including Iran, Turkey and Cyprus, to be referred to collectively in this paper as the Region. Two areas within the Region, namely Mesopotamia and Abyssinia have been considered as centers of origin of cultivated barley (Leonard and Martin, 1963). The evolution of barley varieties as well as improved agronomic practices have been greatly influenced by the semi-arid conditions which prevail in the Region. Barley is grown almost exclusively under rainfed conditions except in restricted areas of Egypt, Iran and Iraq where it receives supplementary irrigation (Kingma, 1973). It is adapted to a wide range of conditions and it is considered as one of the most dependable crops where drought, frost and alkaline conditions are to be encountered (Leonard and Martin, 1963).

The area under barley in the Region during the period 1948-1974 ranged between 8.7 and 10.2 million ha (Anonymous, 1974). In recent years, 1972 to 1974, it was around 8.9 million ha. Average yield was low, 0.9 to 1.2 ton/ha during the period 1972-1974 compared to 3.2 to 3.3 t/ha in Western Europe, and 1.9 to 2.3 in Northern America. Yields in Australia were also low, 0.8 to 1.3 t/ha. The low barley yields realized in the Region might be attributed to several factors, such as adverse environmental conditions (low and unfavourably distributed rainfall, low soil fertility etc.) and to unimproved varieties.

The agronomic practices recommended for barley, as well as for other cereals, will depend on the prevailing conditions in each area. In the low rainfall non-irrigated areas (semi-arid zones), they are naturally different from these practices employed in high rainfall areas or in irrigated areas. Certain aspects of improving agronomic practices will be discussed, with emphasis on rainfed areas.

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1) Rainfed Areas

The agronomic practices in these regions aim mainly at better utilization of available moisture from rainfall by employing such cultural practices which will reduce water run-off and conserve soil moisture.

Improvement of micro-environment. Barley varieties presently grown under rainfed conditions in the Region are more susceptible to lodging than new wheat varieties selected from CIMMYT material. Barley is sown on poorer soils than wheat. In comparative studies also conducted in Cyprus at 27 environments during the period 1968-1972 (Hadjichristodoulou, 1974), the barley variety Athenais consistently outyielded the aestivum wheat variety Pitic 62 and the durum wheat Kyperounda (Fig. 1). Only at one (the highest yielding) location was Athenais outyielded by Pitic 62.

Regression analysus was carried out according to the method proposed by Eberhart and Russell (1966) to study the adaptation of varieties as suggested by Finlay and Wilkinson (1973). The mean yield of all varieties at each environment provided a numerical grading of sites in each season and a useful evaluation of the environment. The regression coefficient for Athenais barley was 1.14 compared to 1.04 for Pitic 62 and 0.79 for Kyperounda. Hence, Athenais barley generally responded better than wheat in the higher yielding environments in this study.

It is evident that in addition to its relatively higher yields than other crops under unfavourable conditions, barley responds to improved conditions under rainfed conditions. Therefore, every effort should be made to improve the crop environment of barley as is already practised for wheat. The main environmental factors that man can improve are soil fertility and water availability. Soil fertility can be improved by fertilizer application, the optimum level of which should be determined in each region and for each rotation system. Research work at the Agricultural Research Institute, Nicosia, Cyprus, by Th.Samios showed that by increasing N fertilizer rate of barley grown year after year in the same fields from 40 kg- 47 kg N/ha, grain yields increased from 2620 to 3140 kg/ha. Soil fertility can be improved also by including legumes in the rotation systems. Ways of conserving water are discussed below.

Rainfall. Rainfall is considered to be the main limiting factor for high yields in the semi-arid regions. Barley yields, which fluctuate considerably from year to year may be affected by both the amount of annual rainfall and its distribution throughout the growing season.

Variations, in grain yield over the season 1968/69 to 1972/72 in a total of 27 locations were not correlated with amounts of annual rainfall. This point is also illustrated in Fig. 2, which shows that similar yields were obtained over a wide range of amounts of annual rainfall. Preliminary results from a multiple regression analysis of the effect of monthly rainfall on grain yield at several locations showed that though the simple correlation coefficients between grain yield and annual rainfall were not significant (0.1 - 0.2), the multiple correlation coefficients were as high as 0.97. These studies have not yet been completed, but they suggest that the distribution of rainfall through the growing season may explain most of the variation in grain yield.

At present neither annual rainfall nor its distribution can be controlled. Therefore, efforts should be made for better storage of water from rainfall for use by barley during the whole growing period. Optimum cultural practices for seed-bed preparation as well as sowing techniques should be developed in each agroclimatic region. Research in this field is in progress in Cyprus by Th.Samios (Barley Production in Cyprus, in these Proceedings), in which various frequencies of cultivation, using a number of implements, and sowing by special drills (Press Drill) are compared. In addition, several practices used to conserve moisture were discussed in three earlier regional meetings (Anonymous, 1972,1974b and 1974c). Efforts should be made to avoid run-off, before germination. In the hilly areas, where run-off is more likely to occur, particularly in the period from sowing until tillering, Press Drill and other drills suitable for contour sowing in furrows should be tested. It is essential to control weeds in all fields because they will compete with the crop for water particularly during grain filling.

Sowing depth. Deep sowing appears to have no advantage over shallow sowing in semi-arid areas. Studies with barley and wheat showed that emergence and plant establishment, tiller number per plant, plant height, grain yield and grain+straw yield are reduced with increased sowing depth (Hadjichristodoulou, Della and Photiades, 1977). Plants from deep sown seeds with their deep seminal roots might be at an advantage over shallow sown plants in low rainfall

areas. However, our studies in Cyprus showed that both establishment and yield were affected by sowing deeper than 5-10 cm and this might be attributed to the fact that plants from shallow sowing developed more roots from their tillers than deep sown plants, and this more than compensated for the shallow rooting pattern of the shallow sown plants. Sowing in heavy soils should be more shallow than in sandy soils and in both cases sowing beyond 5-10 cm should be avoided.

Sowing time. Sowing time of barley is an important factor affecting yields in the rainfed areas of the region (Fig. 3). By early emergence the young seedlings develop deep root systems and make adequate to- growth before the winter, during which growth rate is reduced. It was observed under Cyprus conditions that early grown barley competes better with both broad-leaved and grass weeds. Also, early sown barley reaches heading stage earlier than late sown barley (Fig 4). This will in all probability to coincide with dry hot spells frequently encountered in the rainfed areas of the region at that period. Also plant vigour is reduced by late sowing. This is shown in Fig. 3 where barley yields decreased significantly with late sowing. There was variation between locations and years as regards the effect of sowing date, but generally early sowing in the beginning of November gave the highest yields. Optimum wheat sowing date is later than in barley. Working with wheat in Turkey, Bolton (1974) reported higher yields from early sowing (September) than medium (October) or later (November) sowings.

As rainfall amount and distribution is very variable in the period October-November too early sowing may result in low emergence and thin stands. However, in each region safe sowing periods can be determined by studying rainfall patterns over a great number of years. In Cyprus our experience is that sowing at the beginning of November is safe. The first rains may come at any time after sowing but seeds germinate very well even after having waited for 2-3 weeks in dry soil. To conclude, sowing should be done as early as possible; optimum sowing date will vary from region to region; seedbed preparation should be planned in advance, after harvesting the previous crop, to facilitate early sowing.

Seed rate. Satisfactory plant establishment, a prerequisite for good yields, is affected by seed rate as well as method of sowing and seed-bed preparation. Though barley varieties generally have the ability to adapt their number of tillers to the available space, efforts should be made to use optimum seed rates for each region and variety. Excessive seed rates in low rainfall areas will cause the production of too many tillers per unit area, and if drought prevails during grain filling period, most of the tillers will not bear grain or will produce small and shrivelled grains, giving a low harvest index. Too low seed rates will give thin stands and therefore low yields. Too thin stands do not compete with weeds. It was observed in Cyprus in experimental fields as well as in farmers' fields that normal barley stands compete well with weeds, even with wild oats. Unlike wheat, barley significantly suppresses the establishment of wild oats.

2) Irrigated areas:

Irrigated barley is of minor importance in the Region. An increase in barley production in irrigated or high rainfall areas could be achieved by breeding lodging resistant varieties of high yield potential. As water and nutrients can be provided by man, other improvements on cultural practices can be achieved easily.

CONCLUSIONS

Experimental evidence is presented which shows that barley yields in low rainfall, non-irrigated areas can be increased significantly by improving agronomic practices. In these areas barley can respond to improved environmental conditions even better than wheat. Cultural practices for water conservation and improvement of soil fertility, optimum sowing date and seed rate, and other practices should be investigated in the various agroclimatic zones of the Region. Improvement of agronomic practices, in addition to breeding better barley varieties, could raise the income from non-productive arid lands in the region.

REFERENCES

Anonymous (1972). Regional Wheat Workshop Vol. 11, Agronomy. The Ford Foundation, Beirut

Anonymous (1974a). FAO Production Yearbook for 1974, Vol. 28-1

Anonymous (1974b). Proceedings of the first FAO/SIDA Seminar on Improvement and Production of Field Food Crops. FAO, TF/INT 88 (SWE): 495-530.

Anonymous (1974c). Proceedings of the Fourth FAO/Rockefeller Foundation Wheat Seminar, FAO, AGP:FC/21: 321-395.

Bolton, F.E. (1974). Tillage and Other Agronomic Practices in the Wheat Fallow Cropping System. Proceedings of the Fourth FAO/Rockefeller Foundation Wheat Seminar, FAO, AGP. FC/21, 383-394.

Eberhart, S.A. and W.A. Russel (1966). Stability Parameters for Comparing Varieties Crop Science, 6, 36-40.

Finlay, K.W. and G.N. Wilkinson (1963). The analysis of Adaptation in a Plant-breeding Programme. Aust. J. Agric. Res., 14, 742-754.

Hadjichristodoulou, A., Athena Della and J. Photiades (1977). Effect of Sowing Depth on Plant Establishment, Tillering Capacity and other Agronomic Characters of Cereals. Journal of Agricultural Science, 89, 161-167.

Hadjichristodoulou, A., (1974). Comparative Study of Yield and Quality of Grain Cereals under Rainfed Conditions in Cyprus. Technical Bulletin No. 15, Agricultural Research Institute, Nicosia.

Kingma G. (1973). Aspects of Barley Improvement in the Near East and North Africa. Information Circulated by The Arid Lands Development Program, The Ford Foundation, Beirut.

Leonard, W.H. and J.H. Martin (1973). Cereal Crops. The Macmillan Company, New York.

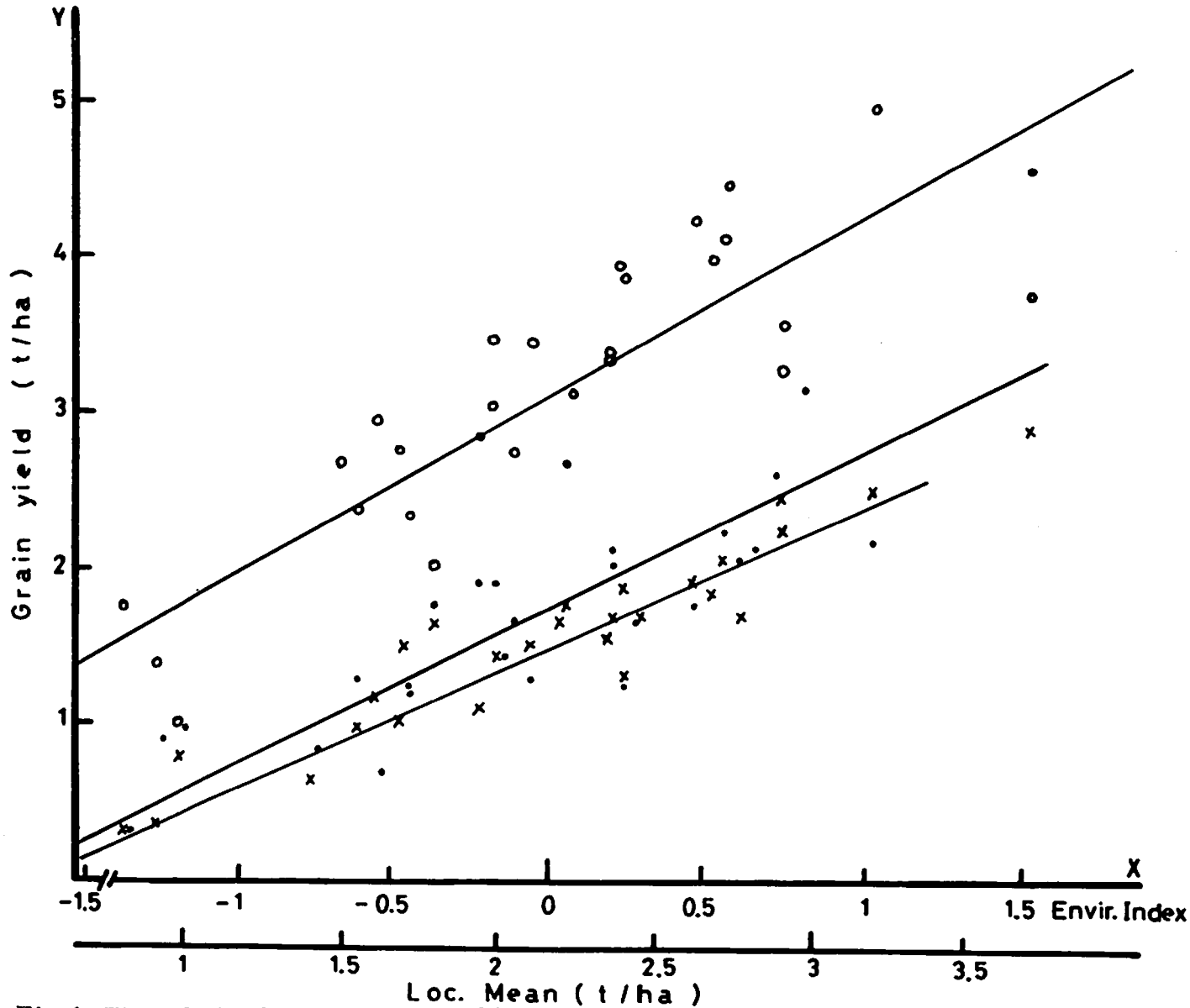

Fig. 1. The relation between grain yield of cereal varieties (Y) and location mean (X).
(o Athenais barley, b=1.14, r=O.86**; • Pitic 62 aestivum wheat, b=1.O, r=O.88**; x Kyperounda durum wheat, b=O.79, r=O.90**).

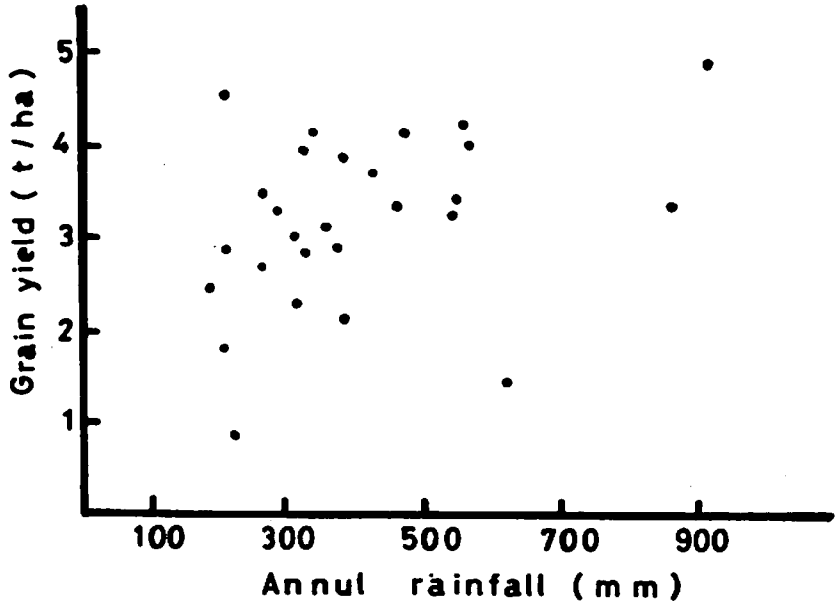

Fig. 2. The relation between grain yield of Athenais barley annual rainfall (r=O. 38 NS)

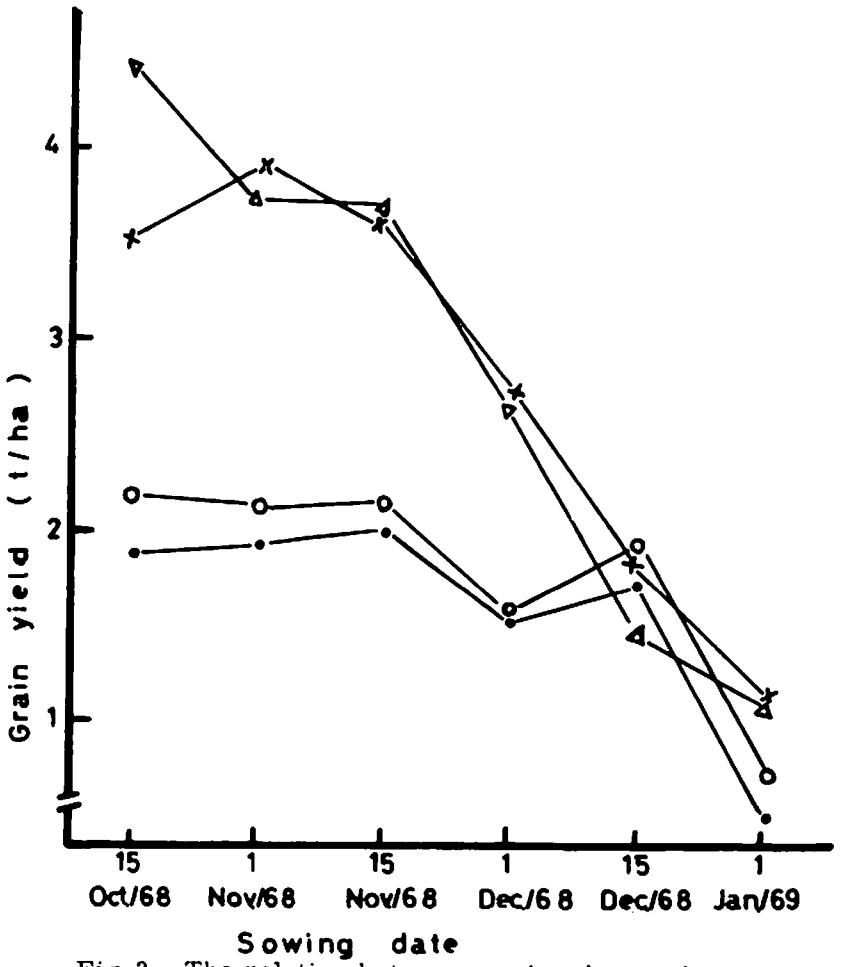

Fig. 3. The relation between sowing date and grain yield of cereals at Athalassa (Sel. 18 barley, X Athenais barley, O Kyperounda durum wheat, • Pitic 62 aestivum wheat).

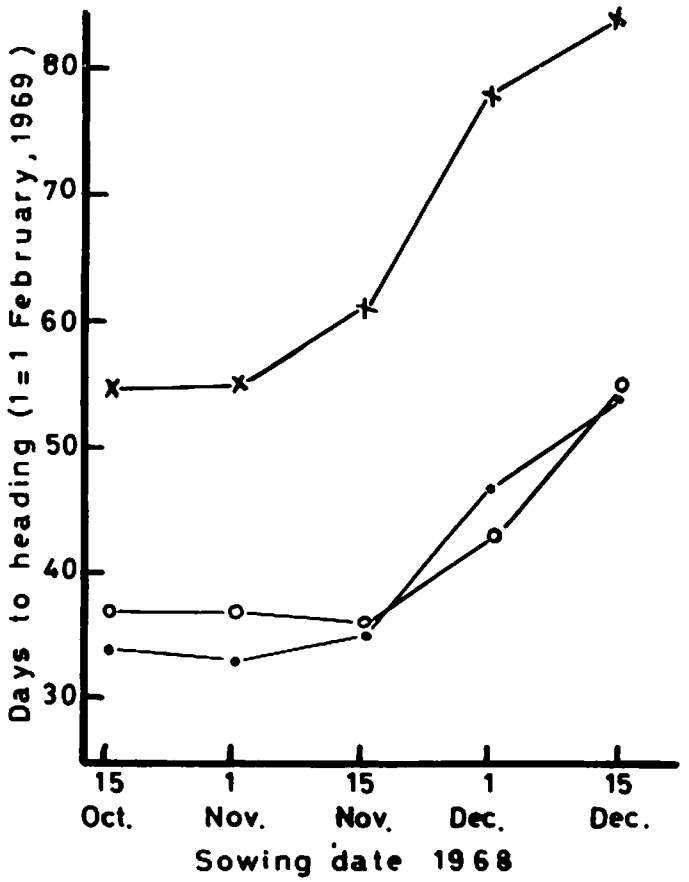

Fig. 4. The relation between sowing date and heading date of Athenais barley (X Dromolaxia, • Athalassa, O Syngrasis).

BARLEY PRODUCTION, UTILIZATION AND RESEARCH IN THE AFRO-ASIAN REGION

By

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Barley workers in the region were requested to provide information on the status of barley cultivation, utilization, agro-environmental conditions, crop protection, and other aspects related to barley production and crop improvement research in their respective countries.

Information provided by national programs from 32 barley producing countries is summarised in the following tables. Countries are grouped into five regions based on geographic locations and agro-climatic conditions (Table 1).

Table 1. Grouping of Countries into Regions

Middle East	North Africa
Afghanistan	Algeria
Cyprus	Egypt
Iran	Libya
Iraq	Morocco
Jordan	Tunisia
Lebanon	
Saudi Arabia	East Africa
Syria	Ethiopia
Turkey	Kenya
Yemen, A.R.	Sudan
Yemen, P.D.R.	Tanzania
South and Far East	**Mediterranean Europe**
Bangladesh	France
Japan	Greece
Korea	Italy
Nepal	Portugal
India	Spain
Pakistan	Yugoslavia

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It is realized that there are sufficient variables within each country and from one country to another to prevent the drawing of any precise regional conclusions. For this reason detailed information for each country is presented separately, in an attempt to provide an overview of the current status and problems concerning barley improvement and production.

Barley Production

Cereals comprise approximately forty-two percent of the world food production and barley ranks fourth with an annual production of about 170 million metric tons (Table 2).

Table 2. Barley in Relation to World Food Production*

	World Cereal Grain Production (M. Mt.)	Percentage of Total Food Production
All Cereal Grains:		42.0
Wheat	377.02	
Rice	320.71	
Maize	311.78	
Barley	168.26	
Others	190.38	

*Adapted from "The Green Revolution: Can We Make it Meet Expectations?" by Norman E. Borlaug - 1976.

Barley, after wheat, is the most important food crop in the Near East and North Africa, occupying around 10 million hectares with an average annual production of 9 million metric tons. Although official figures are not available, the USSR and China are two of the major barley producing nations. Among developing countries in the Eastern Hemisphere, India, Turkey, Morocco, Iran, Algeria, Korea, Iraq, Syria, Tunisia, Libya are the major barley producers.

Barley is an important cereal crop in Afghanistan, Cyprus, Egypt, Jordan, Kenya, Nepal, Pakistan, the Arab Republic of Yemen, and in all the countries of Mediterranean Europe. It is significant to note that barley yields are lowest in North Africa and the Middle East and that the average yield in Mediterranean Europe is approximately three times higher than that of the Middle East and North Africa (Table 3).

Table 3. Average Area Production and Yield of Barley

Region	Area 1000 Ha.	Production 1000 M.T.	Average Yield M.T./Ha.
Middle East	6285	6051	0.96
South & Far East	3871	4725	1.22
North Africa	3453	2974	0.86
East Africa	851	877	1.03
Mediterranean Europe	6479	16361	2.52

(Full details in Appendix I)

Barley yields in East Africa and the South and Far East are less than half of those obtained in Mediterranean Europe. However, average barley yields in Japan and Korea are much higher compared to other countries in the region (Appendix I).. Although barley is generally grown with less proficiency, in poorer and drier areas where wheat is not a profitable crop, it is interesting to note that national average yields of barley are comparable to or higher than those of wheat in Afghanistan, Algeria, Cyprus, Ethiopia, Iraq, Kenya, Libya, Morocco, Nepal, Saudi Arabia, Spain, Turkey and Yemen Arab Republic.

Uses of Barley

In South Asia and the Far East approximately 80 percent of the consumable barley is used as human food. In Ethiopia about 90% of barley is used as cooked food or as home made beverages. In Egypt, Libya, Morocco, Yemen Arab Republic and the Peoples Democratic Republic of Yemen, the majority of the barley produced is used as direct human food. In other countries, barley is primarily used as animal feed and its use for human consumption varies from two to fifteen percent. The use of barley for malt production is also increasing.

Table 4. Uses of Barley

Region	Percent of Production			
	Food	Feed	Malt	Others
Middle East	5	70	20	5
South & Far East	81	12	7	1
North Africa	50	40	8	2
East Africa	30	10	30	30*
Mediterranean Europe	-	60	35	5

* Home make beverages (for full breakdown see Appendix II)

Barley Types

Spring habit barley is grown throughout the region except in the higher elevation areas of Afghanistan, Iran, Turkey, Nepal, Pakistan and India, where spring barley with considerable cold tolerance or winter habit barley can be grown. In Korea and Japan over 90 percent of the area is under winter barley. Cold tolerance is necessary for varieties grown in parts of Algeria, Morocco, Lebanon, Jordan and Iraq.

Local cultivars occupy approximately 90 percent of the area. Within the region the barley crop has been considerably neglected and little has been done to provide and extend seeds of improved varieties or production technologies to farmers. In many countries the entire barley area is still under indigenous land races (Table 5) and yields have remained static for centuries.

Table 5. Types of Barley under Cultivation
(% of Area)

Region	Spring Barley	Winter Barley	Local Cultivars	Improved Varieties
Middle East	60	40	80	20
South & Far East	95	5	80	20
North Africa	100	-	80	20
East Africa	100	-	90	10
Mediterranean Europe	30	70	30	70

(Full breakdown in Appendix III)

Conditions under which Barley is Grown

The majority of the Barley crop in the Middle East and North Africa is grown under 200-450 mm of rainfall (Table 6). In South Asia and the Far East, it is grown with residual moisture or under irrigated conditions.

In areas where only limited (one or two) irrigations can be provided, barley is preferrred to wheat. There are large tracts in the region where the salt content in winter is high and/or soil salinity is a problem and here again, barley predominates.

It is not only the total rainfall but also its distribution during the season that affects the crop yield. In years of erratic rainfall and delayed sowing, the area under barley cultivation increases. In the 200mm rainfall areas, the crop is usually harvested for grain once in every two or three years (in years of good rainfall). During the other seasons the crop is grazed because due to the low rainfall plant growth is too poor for grain production. Grazing of the crop during the early stages of plant growth is a common practice in the Middle East and North Africa.

Table 6. Moisture Levels Under which Barley is Grown
(Area in %)

Region	Irri-gated	500mm	400-500mm	300-400mm	200-300mm	200mm	Resi-dual
Near & Middle East	6	4	14	35	35	6	-
South & Far East	10	10	-	-	-	-	75
North Africa	8	-	23	45	19	-	-
East Africa	3	75	15	7	-	-	-
Mediterranean Europe	3	42	36	10	7	1	-

(Full details in Appendix IV)

The majority of the barley crop in the region is produced in marginal areas with poor soil conditions, low soil fertility and in some cases on newly reclaimed land.

About 80 percent of the barley crop does not receive any chemical fertilizer and weed control measures are practiced in no more than 15 percent area. However, one-fourth of the production area is under medium fertility and higher rainfall conditions, and thus lodging resistant, fertility responsive, disease resistant barley varieties are required.

In Mediterranean Europe and East Africa the majority of barley is also grown under medium to higher fertility conditions.

Table 7. Soil Fertility in which Barley is Grown
(% of Area)

Region	High Fertility	Medium Fertility	Low Fertility	Special Conditions
Near & Middle East	5	35	53	7
South & Far East	2	23	65	10
North Africa	-	25	60	15
East Africa	12	68	15	5
Mediterranean Europe	12	50	35	3

*Saline and Alkaline soil as well as other conditions (complete breakdown in Appendix V)

Barley in the Rotation

Crop rotation plays an important role especially in the mono-crop culture system that largely prevails in the Middle East and North Africa. Barley/fallow is the most commonly practiced rotation. (Table 8).

In the marginal areas, in poor cropping years, fields are grazed and then ploughed. The fields are self-sown from seeds of the previous crop, and may be harvested as a grain crop if the rainfall is more favourable in the next season. In many areas the farmers choice between planting wheat or barley depends on the rainfall and time of planting. Barley/food legumes is another popular crop rotation. In South Asia and the Far East, where double or multiple cropping is widely practiced, barley is often grown after a summer cereal crop. Rice/barley, Maize/barley or millet/barley are also common crop rotations.

Table 8. Crop Rotations involving Barley
(% of Area)

Region	Barley Barley	Barley Wheat	Barley Fallow	Barley Other Crops
Middle East	15	10	55	20
South & Far East	8	2	10	80
North Africa	25	25	30	20
East Africa	18	2	65	15
Mediterranean Europe	15	62	15	8

(Detailed breakdown in Appendix VI).

The Duration of the Barley Crop

As a general rule, barley matures earlier than wheat. This allows barley to escape the late drought and hot winds that periodically affect wheat crops. Barley varieties suitable for Sudan, Yemen P.D.R., The Gulf States, Saudi Arabia, parts of Libya, Egypt, India, Pakistan and Bangladesh should mature between 100 to 150 days. In Kenya and Ethiopia maturation takes about 150-170 days and in the Middle East and North Africa it may take 160-200 days depending upon the location and elevation.(Table 9).

Table 9. Average Duration of the Barley Crop

Region	Number of days
Middle East	180
South & Far East	145
North Africa	190
East Africa	160
Mediterranean Europe	210

At higher elevations in Iran, Afghanistan and the Anatolian plateau where winter barley is grown, the crop duration may exceed 200 days. However, in many cases barley is planted late and its maturity is hastened by warm temperatures during April and May. Where barley is grown as a catch crop, as in Korea, earliness is very important to enable the crop to fit into the overall rotation.

Barley Pests and Diseases

As has been seen, unimproved local land cultivars occupy the major part of the production area in the region and a near equilibrium has been established in the host-parasite relationships. Although the importance of barley diseases, on the basis of prevalence and crop losses, varies from area to area, on the regional level, the diseases caused by Helminthosporium are considered most important. Powdery mildew is judged to be the second most important disease, except in East Africa followed by Stripe rust and Smuts. Scald is indicated to be a serious problem in Afghanistan, Turkey, Portugal, Libya and East Africa countries. Leaf rust is present in most years in Cyprus, Lebanon, Jordan, Greece, Bangladesh, Pakistan, Algeria, Egypt, Morocco and Ethiopia but stem rust is often only of minor importance. The presence of Barley Yellow Dwarf Virus is indicated from Korea, Morocco and Ethiopia and although this virus may be present in more countries its prevalence appears to be limited.

Barley diseases do not cause serious crop losses under poorer crop growing conditions. However, disease susceptibility becomes a major limiting factor in years of good rainfall or under conditions favourable for crop growth. So far very little work has been done to identify and isolate disease resistance genes and the incorporation of multiple disease resistance in agronomically superior genotypes is urgently needed.

Table 10. Diseases of Barley (Ranked According to Importance)

Region	Stem Rust	Stripe Rust	Leaf Rust	Mildew	Helminthosporium	Scald	Smut	Others
Middle East	6	3	5	1	2	5	4	
South & Far East	5	1	6	3	2	7	4	
North Africa	7	5	4	3	1	6	2	Viruses
East Africa	7	4	3	6	2	1	5	
Mediterranean Europe	7	6	3	2	1	4	5	
Overall	7	3	6	2	1	5	4	

(Details in Appendix VII)

Aphids cause serious damage to the crop in several countries. Fritflies, nematodes and stem borers also appear to cause crop damage in some countries. Termites, ants and rodents are perennial problems specially under rainfed conditions. Grainery weevils, lesser grain borers, Moths and Rice Weevils are important stored grain pests in almost all the countries. Bird damage is also a serious problem throughout the region. The following insects are minor and country specific in importance: Armyworm, Barley fly, Cereal leaf minor, Goutfly, Grasshoppers, Hessian fly, Cereal leaf beetle, Locust, Plusia worm, Saw fly and Stink bug.

The Present Barley Research Situation

Improved barley varieties grown in different countries in the region are listed in Table 11. Some of these varieties are bred locally, others are selections from local cultivars, and several are direct introductions from Europe or North America. However, the area under improved varieties is relatively small.

Table 11. Important Commercial Varieties

Mediterranean Europe	Near & Middle East
Bekaa	Tokak 157137
Rivale	Zyfer 160
Elasson	Gem
Albacete	Gumhuriyet 50
Hatif G'Grigon	Arabic Abiad
Union	Arabic Aswad
North Africa	Baladi 25
Saida 183	Roumy
Tichedrett	Arivat
Giza 119	Athenais
Giza 121	Beecher
Sahravi	Deir Alla 106
Bonus	South & Far East
California Mariout	Ratna
Aris 8	Jyoti
Martin	Vijaya
Ceres	Kanpur Lines
East Africa	Kanghori
Bekaa	Sedohadaka
Proctor	Olbori
Research	

The Regional Barley Improvement Program operated jointly by the International Center for Agricultural Research in the Dry Areas (ICARDA) (and earlier by its predecessor ALAD), the International Maize and Wheat Improvement Center (CIMMYT) and the Regional Office of the Food and Agriculture Organization of the United Nations (FAO), Cairo, has for the past several years, prepared and supplied national programs with selected breeding materials, observation lines and yield trials to disseminate sources of new genetic variability. Entries for the nurseries are selected from ICARDA and CIMMYT materials, and advanced lines from the national programs in the region and elsewhere. Cooperative testing of these nurseries provides national programs with valuable information on performance of their best lines under a wide range of agro-climatic and disease prevalence situations. The multi-location testing helps in early identification of high yielding lines with generalized multiple disease resistance and wide adaptability.

The entries are first tested in the Regional Disease and Insect Screening Nursery (RDISN). Approximately 5 to 10 percent of the entries from this nursery are promoted to the Preliminary Observation Nursery (PON) for more detailed testing and evaluation by breeders, agronomists and plant pathologists. On the basis of disease resistance, yielding ability, grain quality and adaptability in the region, about 8 percent of the entries from the (PON) are promoted to the next nursery, the Regional Barley Yield Trial, where yields are analysed alongside one long term check and a local improved variety. The regional crossing block nursery and early segregating populations are also supplied on request. Periodic meetings and workshops, exchange of scientists, and training opportunities are arranged to encourage the flow of germplasm, information and research results between the programs. Barley lines/varieties that have exhibited reasonable yield potential and regional adaptability are listed in Appendix VIII.

In conclusion, after wheat, barley is the most important food and feed crop in the region particularly in the Middle East and North Africa. Its use as direct human food varies from two to over eighty percent and it is largely considered to be a poor man's crop. It is increasingly being used for grazing and for animal feed. The majority of the area is planted to local cultivars traditionally adapted to survive poor crop growing conditions characteristic of low rainfall areas. These varieties lack yielding ability and resistance to diseases and do not respond well to fertilizer application, or improved crop management. Although a number of superior varieties have been identified by some of the national research programs, their commercial cultivation is not possible due to the deficiency of barley seed production and distribution systems in the region.

So far very little effort has gone into Barley Improvement Programs in the region. Keeping in view the higher production efficiency of currently grown barley cultivars as compared to wheat in areas of under 450 mm rainfall, it is logical to expect an increased productivity of this neglected crop with additional research inputs and governmental support.

National Barley Research efforts in the region are characterized by the lack of trained manpower and low priority to barley research and production programs. In twenty out of twenty-five countries in the region, barley improvement work is carried out by overworked wheat staff in their spare time (Table 12). In the five countries where a seperate barley research section exist, their work is handicapped by poor financial support, lack of experienced staff, motivation and research facilities.

Table 12. Status of Barley Research

Region	Independent Barley Program	Varietal Testing	Breeding program	Agronomic research	Plant pathology	Grain Quality	Other
Near & Middle East (11)	1	4	7	6	5	2	1
South & Far East (5)	2	1	4	4	3	2	1
North Africa (5)	1	-	5	4	4	-	-
East Africa (4)	1	2	2	3	1	1	-
Mediterranean Europe (3)	2	3	3	2	3	-	-

The training of young staff in different disciplines of barley improvement and the strengthening of national research competence are essential first steps on the road towards improved barley production in the region. The economics of barley production, in view of the fact that barley is normally produced by poorer farmers, and the necessity of Government established floor prices need urgent consideration before barley can hope to achieve the status in the region that, by virtue of its performance, it rightly deserves.

Average Area and Production Under Barley

Near & Middle East		Area 1000 Ha.	Production 1000 M.T.
Afghanistan		325	369
Cyprus		87	81
Iran		1300	900
Iraq		730	516
Jordan		50	35
Lebanon		10	10
Saudi Arabia		12	18
Syria		700	550
Turkey		3000	3500
Yemen, A.R.		70	71
Yemen, P.D.R.		1	0.5
	Total:	6285	6050.5
East Africa			
Ethiopia		818	829
Kenya		30	45
Sudan		0.22	0.16
Tanzania		3	3
	Total:	851.22	877.16
North Africa			
Algeria		770	500
Egypt		97	132
Libya		164	100
Morocco		2000	2050
Tunisia		422	192
	Total:	3453	2974
South & Far East			
Bangladesh		25	17
Japan		209	539
India		2700	2450
Korea		731	1576
Nepal		26	25
Pakistan		180	118
	Total:	3871	4725
Mediterranean Europe			
France		2634	9496
Greece		365	873
Italy		204	421
Portugal		104	91
Spain		3262	6728
Yugoslavia		312	588
	Total:	6881	1,8197

APPENDIX II

Use of Barley
(Percentage of Production)

North Africa	Food	Feed	Malt	Others
Algeria	5	90	5	-
Egypt	50	35	15	-
Libya	90	10	-	-
Morocco	50	30	2	18
Tunisia	0	90	10	-
South and Far East				
Bangladesh	100	-	-	-
India	80	10	10	-
Korea	97	-	-	-
Nepal	80	10	10	-
Pakistan	50	40	10	-
Mediterranean Europe				
France	-	50	10	40 (export)
Greece	-	90	10	-
Italy	-	40	60	-
Portugal	-	40	60	-
Spain	-	80	20	-
Yugoslavia	-	70	30	-
Near & Middle East				
Afghanistan	-	95	-	-
Cyprus	-	100	-	-
Iran	10	80	10	-
Iraq	2	90	5	-
Jordan	-	100	-	-
Lebanon	-	60	40	-
Saudi Arabia	15	85	-	-
Syria	-	90	-	-
Turkey	-	70	30	-
Yemen, A.R.	80	20	-	-
Yemen, P.D.R.	90	10	-	-
East Africa				
Ethiopia	40	-	3	57(home made beverages)
Kenya	-	30	70	-
Sudan	1	1	97	1
Tanzania	-	-	99	-

APPENDIX III

Types of Barley Under Cultivation
(% of Area)

	Spring Barley	Winter Barley	Local Cultivars	Improved Varieties
Near & Middle East				
Afghanistan	50	50	100	-
Cyprus	100	-	-	100
Iran	60	40	80	20
Iraq	100	-	80	20
Jordan	100	-	70	30
Lebanon	100	-	-	-
Saudi Arabia	100	-	50	50
Syria	100	-	100	-
Turkey	35	65	30	70
Yemen, A.R.	100	-	100	-
Yemen, P.D.R.	100	-	100	-
Mediterranean Europe				
Greece	10	90	5	95
Portugal	100	-	45	55
Spain	30	70	30	70
South & Far East				
Bangladesh	100	-	100	-
India	100	-	70	30
Korea	5	95	25	75
Nepal	100	-	90	10
Pakistan	100	-	80	20
North Africa				
Algeria	100	-	100	-
Egypt	100	-	60	40
Libya	100	-	80	20
Morocco	100	-	80	20
Tunisia	100	-	40	60
East Africa				
Ethiopia	100	-	97	3
Kenya	100	-	-	100
Sudan	100	-	20	80
Tanzania	100	-	-	100

Moisture Levels Under Which Barley is Grown
(Area in %)

	Irrigated	500 mm	400-500 mm	300-400 mm	200 - 300 mm	200 mm	Residual
Near & Middle East							
Afghanistan	30			50	15	5	
Cyprus	3	5	70	15	7	-	-
Iran	2	-	5	50	30	10	-
Iraq	52	8	15	13	12	-	=
Jordan	2	-	10	25	45	18	-
Lebanon	10	-	-	40	50	-	-
Saudi Arabia	5	-	-	60	30	-	-
Syria	3	-	10	20	60	5	-
Turkey	5	10	15	35	35	5	-
Yemen A.R.	-	-	50	50	-	-	-
Yemen P.D.R.	95	-	-	5	-	-	
Mediterranean Europe							
Greece	-	20	70	10	-	-	-
Portugal	-	90	10	-	-	-	-
Spain	8	25	25	20	20	2	-
South & Far East							
Bangladesh	-	-	-	-	-	-	100
India	20	-	-	-	-	-	80
Korea	-	100	100	-	-	-	-
Nepal	10	-	-	-	-	-	80
Pakistan	30	-	-	-	-	-	70
North Africa							
Algeria	-	-	-	90	5	-	-
Egypt	40	-	-	-	-	60	-
Libya	15	-	-	-	85	-	-
Morocco	-	-	-	15	80	5	-
Tunisia	-	-	-	20	80	-	-
East Africa							
Ethiopia	3	70	17	10		-	-
Kenya	-	90	10			-	-
Sudan	100	-	-	-	-	-	-
Tanzania	-	-	-	100		-	-

APPENDIX V

Soil Fertility Under Which Barley Is Grown
(% of Area)

	High Fertility	Medium Fertility	Low Fertility	Special Conditions*
South & Far East				
Bangladesh	-	-	100	
India	-	20	80	
Korea	10	50	40	
Nepal	-	20	80	
Pakistan	-	30	70	
North Africa				
Algeria	-	30	60	10 (marginal)
Egypt	-	40	50	10 (newly reclaimed)
Libya	-	10	50	40 (marginal)
Morocco	-	20	80	
Tunisia	-	30	70	
East Africa				
Ethiopia	10	70	20	
Kenya	70	30	-	
Sudan	10	90	-	
Tanzania	-	99	1	
Near & Middle East				
Afghanistan	-	30	70	
Cyprus	3	70	27	
Iran	-	30	70	
Iraq	-	50	30	20
Jordan	10	30	60	
Lebanon	10	40	50	
Saudi Arabia	-	20	80	
Syria	-	10	90	
Turkey	10	30	60	
Yemen, A.R.	-	60	40	
Yemen, P.D.R.	-	70	30	
Mediterranean Europe				
Greece	10	50	40	
Portugal	30	70	-	
Spain	8	40	52	

* Saline and Alkaline Soil as well as other conditions.

APPENDIX VI

Crop Rotations Involving Barley
(% of Area)

	Barley Barley	Barley Wheat	Barley Fallow	Barley Other Crops
Near & Middle East				
Afghanistan	5	5	70	20
Cyprus	5	30	40	25
Iran	-	-	-	-
Iraq	5	5	50	40
Jordan	-	-	40	60
Lebanon	5	20	10	65
Saudi Arabia	30	-	20	40
Syria	20	-	60	20
Turkey	15	20	50	15
Yemen, A.R.	-	-	80	20
Yemen, P.D.R.	-	-	100	-
Mediterranean Europe				
Greece	5	90	0	5
Portugal	5	85	5	5
Spain	20	40	30	10
South & Far East				
Bangladesh	-	-	-	100
India	10	5	10	70
Korea	4	0	0	96
Nepal	10	0	20	60
Pakistan	5	-	10	80
North Africa				
Algeria	25	25	25	25
Egypt	50	-	-	50
Libya	25	25	25	25
Morocco	25	10	50	25
Tunisia	-	95	5	-
East Africa				
Ethiopia	15	1	75	9
Kenya	60	25	10	5
Sudan	-	-	-	100

APPENDIX VII

Disease of Barley
(Ranked According to Importance)

	Stem Rust	Stripe Rust	Leaf Rust	Mildew	Helmin-thosporium	Scald	Smut	Others
Near & Middle East								
Afghanistan	4	1	6	1	3	2	4	
Cyprus	-	-	1	3	2	-	4	
Iran	6	2	5	3	1	7	4	
Iraq	-	-	-	-	1	-	2	
Jordan	6	7	3	2	4	-	1	
Lebanon	-	-	2	1	4	-	3	
Saudi Arabia	-	-	-	-	-	-	-	
Syria	-	-	-	1	-	-	-	
Turkey	5	7	6	1	2	3	4	
Yemen, AR	-	-	-	-	-	-	-	
Yemen, PDR	2	1	-	-	-	-	-	
Mediterranean Europe								
Greece	-	-	3	2	1	-	-	
Portugal	-	-	-	3	2	1	4	
Spain	4	4	4	2	1	-	3	
South & Far East								
Bangladesh	2	-	3	-	1	-	4	
India	6	1	5	3	2	-	4	
Korea	5	5	5	4	2	6	3	1
Nepal	4	1	5	1	2	6	3	
Pakistan	3	1	2	2	4	5	4	
North Africa								
Algeria	-	3	2	5	1	5	4	
Egypt	4	-	2	3	1	-	-	
Libya	-	-	-	2	-	3	1	
Morocco	-	-	3	5	1	-	2	4(viruses)
Tunisia	7	6	4	3	1	5	2	
East Africa								
Ethiopia	8	5	3	7	2	1	4	6
Kenya	4	3	5	-	2	1	6	
Sudan	-	3	3	-	-	-	-	
Tanzania	6	5	3	4	1	2	-	

APPENDIX VIII

Barley Varieties/Lines with Higher Yield Potential and Wide Adabtability In The Region

1. Giza 121
2. Arrivat x Local D8
3. Beecher
4. Aurore x Esperance LB-2L-9L
5. As54-Tra(Cer-Tol I)(Avt x Tol I-Bz) Yt/Pro-Tol I XV 2780-IC-5v-2M
6. 2762 x Beecher
7. Arimar x 2763
8. Composite Cross 89
9. Cross Cr.257/36
10. WI 2197
11. Roho
12. Cr 115-Por x 6-1y-1y-103C

BARLEY IN THE LEY FARMING SYSTEM*

By

John B. Doolette**

Barley or wheat fits equally as well into a ley farming system provided that the ley farming system fits the particular environment. So that having understood the basic concepts and principles of this cropping system it is necessary to see whether the environmental constraints can be met. The pattern or shape of the system as it develops in a specific region will invariably reflect the level and reliability of rainfall, and to some extent the production goals peculiar to that area, although ultimately these may change when a particular enterprise comes to express itself better in the newly developed system.

Description of the System

The concept is a simple one. The cereal crop is grown in rotation with a free seeding, self-regenerating, annual, forage legume and it is intended that the legume will dominate the pasture phase of the rotation and provide soil nitrogen, improve the physical fertility of the soil, help with the control of weeds and cereal disease, and provide large quantities of forage which may be used by animals. Ultimately the grazing animal becomes an intimate part of the system because of the forage produced. It is an extremely useful management tool as well. However, the animal is not necessary to justify the system although it is hard to visualize a region in which it would be excluded. Thus, this particular land use system links together cereal crops and livestock production into a management system.

There are some important principles to understand which do not appear in the usual cropping systems of the region and these revolve mostly around the function of the legume plant.

The legume has the ability to fix atmospheric nitrogen through its symbiotic relationship with rhizobia bacteria provided that inoculation and nodulation are satisfactory.

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* Ley: Arable land used temporarily for pasture; the pasture phase of a rotation of cereals and pastures.

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Nitrogen accumulation as a result of this symbiosis is greater for the annual forage legumes than the grain legumes and depends on the extent of the root growth. Perhaps, for practical purposes this can be "correlated with" top growth so that nitrogen accretion is only likely to be substantial if the plants grow vigorously.

The annual forage legumes produce dense stands of herbage and roots when properly fertilized particularly with phosphate. There are adequate examples of a direct relationship between forage yield and phosphate application.

The production of adequate seed, a large percentage of which is "hard" and will not germinate in the autumn after its production is the mechanism by which the legume regenerates itself after a short cropping phase. Preserving this close to the surface by shallow cultivation in the cropping phase is of extreme importance.

Some control is necessary in the exploitation of the forage by the grazing animal to maximize seed production, fertility build up, weed control and animal income.

There is good evidence to show that under a wide range of conditions the system works best on a ratio of one cereal crop: one year of pasture although this is influenced by the quality of the environment.

The system developed in Australia in response to several pressures, the principal one being the exhaustion of natural fertility of the soil. Early farmers, unaccustomed to their new environment, grew successive crops of wheat and noticed a rapid decline in yield as a consequence of a rapid fall in soil fertility. Continuous cropping used up the natural fertility. A fallow-wheat rotation plus the use of phosphate and improved varieties succeeded in lifting yields temporarily. Bare fallow conserved moisture in a limited number of cases, broke down the organic matter to supply the nitrate-nitrogen needs of the crop, helped spread the work load when the only form of traction was horses, and helped with weed control. This heavy cultivation program destroyed organic matter and soil structure, promoted soil erosion and its benefits were short-lived. The new system evolved in a desperate response to these pressures and it could be argued that exactly the same pressures exist in North Africa and the Middle East at the present time.

The key factor in the system is the legume. The system has been developed in Mediterranean climates and the subterranean clover (Trifolium subterraneum) and medicago (Medicago sp.) varieties used, are typical Mediterranean annuals. They germinate with the autumn rains, grow under favorable conditions until seed is set in the spring or early summer and survive the dry summer months as seed. The success of a variety depends not only on the vigour of its winter-spring growth, but also on its ability to produce a large quantity of seed so that in regeneration, dense seeding populations can exert strong competitive pressures against weeds. The seed must have a protective mechanism against germination until the growing conditions are favourable.

In a good deal of North Africa and the Mediterranean countries where the soils are neutral to alkaline the annual species of the genus Medicago grow vigorously and the development of the system is based on this material. The system can be constructed, however, under different soil conditions using varieties of Trifolium subterraneum or indeed other annual forage legumes. The important issue is the necessity of establishing the system using a variety that responds well to the environment.

Environmental Constraints

The environmental constraints to the application of the system are set in terms of those for the successful and economic expression of the annual forage legume itself. The successful variety displays vigorous growth in winter and spring and also produces large quantities of seeds. Donald in discussing factors which influence the distribution of subterranean clover in Australia (Donald 1960), considers that the paramount criteria of the success or failure of a strain in a given habitat is the weight of seed produced, as seed production is the prime ecological index of the fitness of an annual plant to its environment. There are broad climatic boundaries which Donald defined in the following terms:

- The arid boundary beyond which soil moisture deficiency or atmospheric aridity causes flower abortion.

- The warm boundary beyond which the plants experience insufficient cold to allow flower initiation to occur.

The cold boundary beyond which frosts during flowering reduce or supress seed production or where low temperatures may limit flower induction.

In terms of commercial exploitation the use of existing commercial cultivars is probably confined above the 250 mm rainfall isohyet and between the 2-3°C and 12-13°C winter isotherms. In the Mediterranean climates these boundaries are the main constraints but in the semi-arid Mediterranean or fertile crescent climates an additional constraint of rainfall distribution in relation to temperature may occur. Here where useful rainfall is usually confined to the cold months, temperatures may well drop before there is adequate moisture for strong establishment. It is possible to extend these boundaries by development and introduction of new varietal material.

If the environment is adequate for the system to work, barley may be used as the cereal crop with or as a replacement for wheat. In fact, in many situations barley may fit into the rotation more easily than wheat.

The Shape of the Rotation

Once the broad technical parameters have been defined, the shape of a crop rotation on any farm will reflect financial considerations and the farmers preference. However, it is possible to project broad ideas on a regional basis.

In the regions where average annual rainfall varies between 350 mm and 450 mm it is possible to have a cropping intensity of at least one crop in two years within the framework of the annual forage legume rotation. Especially in loamy, easy-to-work soils, a rotation of barley one year and medic pasture in the alternate year, is not only practicable but extremely desirable.

Large regions of Australia have developed this way. The following table which contains actual production figures for statistical districts illustrate the position. They give area and yield figures for two periods, 1931-40 and 1951-60. In the period 1940-50 the rotation was being installed:

It is clear from the yield figures that 1931-40 was a period when there was no attempt to establish this rotation and that 1951-60 was the first period following the establishment of the system. It was reasonable to assess the effect. It is interesting to note that the variety remained the same in all zones and in both periods.

Statistical Districts	Time Period	Rainfall mm	Area Ha.	Yield Tons/ha.	Kgs/Cm of rain
Zone A	1931-40	420	6880	1.05	25
	1951-60	475	9350	1.68	35
Zone B	1931-40	365	5140	1.03	28
	1951-60	380	7000	1.59	42
Zone C	1931-40	330	1820	0.84	25
	1951-60	355	4500	1.38	39
Zone D	1931-40	330	1090	0.63	19
	1951-60	355	2070	1.50	42

Zones A and B fit clearly into the region of rainfall between 350 mm and 450 mm and in these areas fertility increased more rapidly than it was being depleted and on many farms cropping intensity increased from five crops in ten years to six crops. During the same period grain protein levels also increased. On heavier soils in the moderate rainfall regions particularly where the rotation is based on subterranean clover, it will be usual to have two crops following two or three years of pasture. In this case barley invariably follows after wheat. So that in these two examples, barley fits very well into the ley farming rotation in the moderate rainfall regions. As rainfall drops below 350 mm it becomes hard to sustain a rotation of 1:1 (one crop to one year of pasture). By way of example, in the Zones C and D in the table above, the ratio of crop to total area in the period 1951-60 was 2.8 and 3.5 respectively. Although they have the same average rainfall, that in D is somewhat more variable than that in C.

In livestock intensive situations barley and an annual forage legume, particularly medic, fit very well together and in many respects are better than oats because of the earlier vigour of barley. There are three separate situations where barley may be fitted into such a situation.

The first is as a cover crop in the establishment of a medic pasture. This is particularly useful in drier areas where it is intended to have two or three years of medic pasture between crops. This means that a lower seed rate can be used when

establishing the medic. A light seeding of barley (20-30 kgs/ha) which is grazed 8-10 weeks after planting increases the forage yield and hence the profitability in the year of establishment.

The second situation is as the cereal crop in the cropping sequence. Here in animal intensive situations barley may be grazed up until the mid-tillering stage and then allowed to recover for grain. In moderate rainfall areas the effect of this defoliation on subsequent yield is slight. Obviously, it is greater in years of a dry finish than in a good season.

The third possibility is to oversow barley into a well established medic pasture in the autumn with the idea of cutting it all for hay.

So overall barley fits into the ley farming system well, provided that the ley farming system fits the environment.

EFFECT OF CLIPPING ON FORAGE, HAY AND GRAIN PRODUCTION FROM BARLEY, WHEAT AND TRITICALE

By

Elpis A. Skorda*

Introduction

In Greece barley is primarily grown for grain. In a few areas, it is used as temporary winter pasture, and then left to produce grain. There are also limited areas where barley is used as hay, but no small grain crop is used for sileage.

Experimental evidence indicates that barley, wheat, and oats, when sown early, or at the normal planting date under favorable growing conditions, produce very good vegetative growth and satisfactory grain yield following one or two clippings for forage (Skorda, 1971, 1973). When all these crops were harvested at the milk stage without any previous clipping, they produced 7,650 to 11,130 hay kg/ha.

The increased use of barley and/or other small grains for forage is likely to follow the rapid expansion of the cattle and sheep industry which has occured in Greece during the last five years. Moreover, growing barley for hay will encourage an increase in the overall corn acreage, an important consideration since Greece imports more than 700,000 tons of corn each year. This is because barley for hay is usually harvested before the normal sowing date of corn, and hence corn can follow barley in the same field.

The objectives of these studies were to compare the forage potential of fall-sown barley, wheat and triticale and to determine the influence of stage of growth on the yield and quality of the forage, hay and grain produced.

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Materials and Methods

Three fall-sown field experiments provided the material for these studies. Beka (2 rowed barley), G-02763 (Bread-Wheat) and G-04756 (Triticale), were the varieties included in the field trials. The experiments (one for each species) occupied adjacent sites in the same field. The experimental layout was a randomized complete block design with four replications. Each plot consisted of seven rows, 26 cm apart and 9 m long.'

Treatments were as follows:

1) harvesting for grain only (normal sowing date),

2) harvest for grain (early sowing date),

3) one clipping (Clip I) for forage at jointing stage and later harvest for grain,

4) two clippings (Clip II) and then harvest for grain,

5) one clipping and harvest for hay at milk stage, and

6) no clipping and harvest only for hay from different plots at heading, flowering, milk and dough stages.

Treatments 2, 3, 4, 5 and 6 were all seeded early.

In order to determine the forage and hay yield, an area of $10x4m^2$ was harvested from each treatment and weighed. Total dry weight (DWT) and per cent dry weight (PDWT) were estimated after oven drying at 80^oC for 48 hours. The oven-dried samples were ground through a 20-mesh screen and the ash content was estimated by heating sub-samples at 600^oC for 12 h. Also, by using sub-samples Ca, P, Na, and Mg, protein content, oil, crude fibre and nitrogen free extracts were estimated.

R E S U L T S

Effect of Clipping on Grain Yield

Grain yield from barley, wheat and triticale without any clipping and after one or two clippings are presented in Table I.

No significant differences were observed for yield between early and normal sowing dates in the three species. The yield of barley increased significantly when plants were clipped once, whereas it decreased after two clippings but this decrease was not significant at the 5% level. One clipping did not affect yield of wheat but two clippings decreased it slightly. The grain yield of triticale was decreased under both one and two clipping regimes. Although the data were not strictly comparable for the species it is clear that wheat was the highest yielding species and barley was the lowest.

Effect of Clipping on Forage and Hay Yield

Barley and wheat produced almost the same amount of forage yield with one or with two clippings, whereas triticale gave a higher yield of forage with both one and two clippings. Hay yield was influenced, to varying degrees, by stage of maturity at harvesting. Dry yield weight increased significantly from boot to dough stage (Table II). Percent dry matter increased also with the later cutting dates. There was variation in the combined hay and forage yield at adjacent stages of growth as well as between the three species. The low yield of barley was attributed to mildew infection.

One clipping decreased the hay yield at the milk stage, but the combined hay and forage production at this stage yielded the same amount of dry matter as the hay yield from plants at the milk stage that were not subjected to clipping. The highest yield of each species was obtained from cutting at the dough stage; for earlier clippings a yield reduction was observed.

Effects of Clipping on some other Agronomic Characteristics

Clippings increased frost injury in wheat and barley when cold temperature prevailed immediately after clipping; it also delayed heading date, decreased height and lodging, and in some cases increased test and 1000-kernel weight in all three cereals. In triticale grain protein content and sedimentation test value were negatively affected by clipping (Table I).

Influence of Cutting Date on Chemical Composition of Hay

Crude protein, oil, ash, Ca, P, Mg, and Na content decreased gradually with advancing maturity, whereas crude fibre and nitrogen free extractives increased (Table II, III). The ash content was markedly higher ($P < 0.05$) for all species harvested at the jointing stage compared to subsequent harvesting dates. Barley had the highest ash content at the jointing stage, as compared with wheat and triticale which had almost the same concentration.

No differences were apparent among the three species for crude protein content at the initial cutting, (Clip I), except that Triticale contained a somewhat lower quantity than Wheat or Barley. As expected, the earlier the cut, the higher the protein content of the forage. Cutting cereals for hay at the vegetative stages resulted in a higher protein content than cutting at the flowering or seed stages. Protein content was found to be high at the jointing stage and to decrease rapidly until flowering stage (Table II). At the time protein content appeared to remain constant after jointing stage because in the first and second clipping the plants had all their leaves, which was not the case at the more advance stages. There was no difference in protein content between the first and second clipping of forage; however, the difference in ash content was very high between the first and second clipping. The ash content at the second clipping was very close to that at the boot stage. There were no consistent differences among the three species for protein yield at clip I and II. However, there were differences at the other stages of cutting, barley producing the highest yield of crude protein per hectare at the heading stage, wheat at the dough stage and triticale at both the heading and dough stages. In terms of the total annual yield of crude protein, wheat gave the highest yield followed by barley and triticale, producing similar levels.

The P content decreased with stage of harvesting, but there were no significant differences between species. Barley contained more Ca than wheat and wheat more than triticale at the same stages of cutting. Barley had the highest content of Mg and Triticale contained more oil than the other two species.

The crude fibre fraction of the forage increased from the jointly to the boot stage; and thereafter plateaued. The nitrogen free extracts of the forage increased from the jointing to the boot stage after which the rate of increase was greatly reduced as the head began to fill.

Close association were found among many of the parameters studied (Tables II, III). For protein and ash content there was a high positive correlation.

DISCUSSION

Winter temperatures in Greece are suitable for prolific growth of small grains, which results in considerable vegetative production during the winter months. Growth may be fairly uniform during this time of the year or may be only briefly interrupted. Only in limited areas in the northern region growth may be erratic. Therefore cereals can be used for animal feed during a period when there is no vegetative growth of other plants including alfalfa.

In previous experiments it has been shown that small grains recovered completely, when clipped 5 to 6 cm from ground level (Skorda 1971, 1973). Holt (1962) reported that carbohydrate reserves and greater residual leaf area after clipping helped cereals to recover more rapidly. Moreover, with an early sowing date, cereals may develop good root systems which enable them to recover more rapidly after cutting. Consequently an early sowing date ensures abundant vegetative growth at the end of winter or in early spring. Clipping also helps to reduce or restrict lodging, and mildew and other disease infections which are common especially when cereals are early sown. It thus seems that clipping of barley, wheat and triticale during the fall and winter months in a season of adequate rainfall, will not adversely affect the yield of grain but may actually increase it.

The extent to which the extra forage yield can offset subsequent reduction in grain yield varies with weather conditions. It was found that as many as four cuttings did not reduce grain yield when favorable weather conditions prevailed (Skorda, 1971). Moreover, the forage from Clip I and Clip II was of very good quality as indicated by the chemical composition. Hawkings and Autrey (1955) reported that the digestability of oat forage dry matter was 79.4% in comparison to 58.8% for alfalfa hay. Besides, cereals produce this excellent quality forage, at a time when no other high protein content green feed is available.

The dry matter yield of hay increased with each stage of growth until the dough stage after which the yield remained constant, similar results were obtained by Meyer et al. (1957) for oats.

Although the experimental design did not allow for a valid test among the species, the data indicated that wheat and triticale were the highest hay yielders (as was found also by Burgess et al. (1973) for wheat); barley gave the lowest yield and this was contrary to the findings of Fisher and Fowler (1975). All cereals gave satisfactory amounts of forage and grain yields with one or two clippings (Skorda 1973). However, as pointed out by Tingle and Dawley (1974) dry matter yield does not necessarily mean high digestible dry matter yield. Maximum yield of all three species was obtained by the delaying of harvest until the seed stage, but protein content was comparatively low at this stage in barley when compared with wheat and triticale. The highest yield of crude protein was at the heading, and harvesting at this stage would give a better balance between dry matter yield and protein content. Moreover, it is interesting to note that harvesting barley for hay at this stage facilities double cropping and the use of the same field for corn in the normal planting season. According to Meyer el al. (1975) the digestible protein content as determined in digestibility trials, followed the same trend during advancing maturity as the crude protein. The ash content was highly and positively correlated with digestible dry matter (Fisher and Fowler, 1975).

The data from this study indicate that for grain or hay production it is economically feasible to pasture or clip barley, wheat and triticale one or more times before grain harvest in years of favourable conditions in many areas of Greece and perhaps in other countries with the same environmental conditions. This pasture should be considered as a potential and economic source of protein for livestock enterprises. Cereals also produce a considerable amount of good quality hay when harvested between the heading and milk stages. In dry areas where alfalfa production may be uncerain they can thus provide an excellent alternative conserved fodder and possibly increase livestock carrying capacity by reducing the risk of insufficient availability of feed.

TABLE I. GRAIN YIELD, TEST AND 1000-KERNEL WEIGHT, LODGING, SEDIMENTATION VALUE, PROTEIN CONTENT %, FROST, HEADING TIME AND HEIGHT OF BARLEY, WHEAT AND TRITICALE AFTER 0, 1 & 2 CLIPPINGS .

VARIETY / TREATMENT	GRAIN YIELD						TEST WEIGHT (KG)			1000-KERNEL WEIGHT(G)		
	BEKA		G-02763		G-04756		BEKA	G-02763	G-04756	BEKA	G-02763	G-04756
	KG/HA	%	KG/HA	%	KG/HA	%						
EARLY SOWING	3847	100	5846	100	4488	100	60.2	77.8	65.4	33.8	35.0	36.0
NORMAL SOWING	3908	102	5774	99	4630	103	61.2	79.1	65.1	33.8	35.0	36.0
AFTER ONE CUT	4540	118	5888	101	4155	93	61.8	80.6	66.9	33.8	38.1	37.0
AFTER TWO CUTS	3533	92	5155	88	4021	90	59.4	79.3	67.4	30.0	35.6	38.0
LSD 0.05	455	11.8	N.S.		306	6.8	N.S.	N.S.	1.4	N.S.	N.S.	N.S.
0.01	654	17.0			440	9.8			2.1			

	LODGING						SEDIMENTATION VALUE		PROTEIN CONTENT %		
	%		%		%						
EARLY SOWING	48	53	90	75	100	61	32	24	16.1	12.5	13.3
NORMAL SOWING	0	0	63	68	100	68	39	25	14.9	13.3	13.4
AFTER 1 CUT	0	0	15	20	68	70	37	21	15.4	12.3	12.8
AFTER 2 CUTS	0	0	23	20	48	53	39	17	13.9	12.5	10.0
LSD 0.05							N.S.	3	N.S.	N.S.	1.3
0.01								4			1.8

	FROST (1)			HEADING TIME			HEIGHT (CM)		
EARLY SOWING	1.5	1.5	1.1	19*	25	16	106	115	153
NORMAL SOWING	0.5	0.5	0.5	27	28	21	95	103	152
AFTER 1 CUT	3.0	3.0	0.3	22	27	19	99	103	142
AFTER 2 CUTS	3.0	3.0	0.0	25	29	22	89	95	139
LSD 0.05				8.5	0.8	1.3	4.9	7.6	7.0
0.01				11.8	1.2	1.9	6.8	10.6	9.8

* From 1st April

TABLE II. FORAGE, AND HAY KG/HA, CRUDE PROTEIN AND ASH PERCENT OF FORAGE AND HAY OF BARLEY WHEAT AND TRITICALE

	FORAGE & HAY KG/HA			CRUDE PROTEIN CONTENT%			ASH CONTENT %		
VARIETY	BEKA	G-02763	G-04756	BEKA	G-02763	G-04756	BEKA	G-02763	G-04756
STAGE									
JOINTING (1ST CUT)	598	640	738	33.70	33.83	30.64	19.00	15.20	15.47
JOINTING (2ND CUT)	1322	1300	1496	31.94	34.64	28.64	11.61	12.42	11.97
BOOT	5385	8223	7490	15.78	12.97	12.28	11.66	11.48	10.40
HEADING	8598	10115	9093	12.38	11.42	10.69	9.95	9.01	8.90
FLOWERING	8408	10723	10483	11.08	11.81	8.59	9.19	9.31	8.01
MILK AFTER 1 CUT	8048	11173	10645	8.21	8.52	6.04	6.94	5.58	5.80
MILK	8918	12980	13185	8.94	9.69	7.84	7.64	6.88	6.14
DOUGH	11548	14540	15450	6.97	9.62	6.28	7.98	5.80	5.71
LSD 0.05	2091	2902	1772	2.27	1.87	1.66	1.23	0.96	0.67
LSD 0.01	2925	4060	2480	3.08	2.55	2.26	1.67	1.30	0.91

TABLE III. PHOSPHOROUS, MAGNESIUM, CALCIUM, POTASSIUM, OIL, CRUDE FIBRE AND NITROGEN FREE EXTRACTS CONTENT (%) OF FORAGE AND HAY OF BARLEY, WHEAT AND TRITICALE.

	P			MG			Ca			Na		
VARIETY / STAGE	BEKA	G-02763	G-04756	BEKA	G-02763	G-04756	BEKA	G-02756	G-04756	BEKA	G-02763	G-04756
JOINTING 1 CUT	0.26	0.26	0.27	0.40	0.21	0.23	0.70	0.63	0.62	0.195	0.066	0.063
JOINTING 2 CUTS	0.18	0.21	0.20	0.29	0.19	0.14	0.91	0.60	0.53	0.130	0.045	0.044
BOOT	0.16	0.17	0.17	0.21	0.13	0.12	0.66	0.46	0.39	0.061	0.050	0.038
HEADING TIME	0.16	-	0.15	0.24	-	0.10	0.65	-	0.35	0.130	0.052	0.034
FLOWERING	0.13	0.13	0.12	0.13	0.13	0.10	0.64	0.46	0.35	0.172	-	0.036
MILK	0.11	0.10	0.09	0.12	0.10	0.09	0.55	0.31	0.25	0.130	0.046	0.013
MILK AFTER 1 CUT	0.11	0.09	0.09	0.18	0.09	0.09	0.39	0.22	0.21	0.080	0.027	0.018
DOUGH	0.11	0.11	0.10	0.12	0.12	0.09	0.44	0.25	0.23	0.069	0.024	0.012
LSD 0.05	0.042	0.026	0.021		0.04	0.021	0.27	0.06	0.042		0.010	0.008
LSD 0.01	0.057	0.028	0.028		0.06	0.028	-	0.08	0.057		0.014	0.010

	OIL			CRUDE FIBRE			NITROGEN FREE EXTRACTS		
JOINTING 1 CUT	2.30	2.86	3.39	13.00	16.27	15.84	29.64	30.94	36.32
JOINTING 2 CUTS	3.03	3.06	3.26	15.06	16.13	16.22	37.01	32.92	38.61
BOOT	1.81	1.24	-	27.55	28.95	-	44.95	48.07	-
HEADING TIME	1.59	1.52	1.71	31.41	27.74	30.33	43.42	51.85	47.09
FLOWERING	1.67	1.44	1.90	29.89	29.12	28.82	45.09	48.64	50.01
MILK	1.46	1.33	1.80	27.25	23.81	27.76	55.51	59.46	56.47
MILK AFTER 1 CUT	1.99	1.47	1.64	23.04	18.67	27.30	57.47	66.86	58.56
DOUGH	1.42	1.43	1.57	27.41	23.43	28.20	55.6	59.31	58.24

FARMERS AND MARKETS: IS BARLEY THE ANSWER ?

By

Donald Winkelmann

Discussion about the adequacy of technology must begin with the farmer and the environment in which he operates. Today's conventional wisdom regards the farmer as seeking to augment income while keeping risk within tolerable limits, as sensitive to the nuances of his environment, and as effective in the administration of the resources at his disposal. There is ample evidence that farmer response to new technologies is consistent with these assumptions.

It is widely held that barley provides more yield and more stable income than does wheat where rainfall is low and variable while wheat is preferred where rainfall is more abundant. Data from yield trials and country averages suggest that wheat's superiority over barley occurs after rainfall reaches levels well in excess of 500 mm. At what level this superiority occurs depends on many factors. Important among these factors are relative prices of the two cereals and the distribution of rainfall. For countries in which wheat and barley are grown for livestock feed, relative prices tend to reflect digestible nutrients. For countries in which both are primarily for human consumption, barley's relative price is well below that of wheat.

Research aimed at increasing barley's yield and at increasing the range of utilizations in which it can be used could lead to substantial increases in the area devoted to the crop.

Technological change in agriculture is not a new thing. New methods, new inputs, new varieties, even new crops have followed one another throughout history. What distinguishes today's scene from that of the past is today's strong sense of urgency and the emphasis on promoting change through institutional efforts.

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Some of these efforts have been notable successes, others have been notable failures. Side by side are examples of new technologies which have literally swept the countryside and others which, while apparently promising much, have been rejected out of hand. Efforts to promote change could be enhanced, if factors which contribute to the rapid spread of new technologies could be identified.

The subject of this discussion is how adoption of new barley production technology can be promoted. The focus is on developing countries where the need for change is greatest. Most of the observations emerge from a series of adoption studies in which CIMMYT participated. The discussion opens with assumptions about farmer behavior, and focuses on elements which might influence farmer response to new technology.

The Farmer

The farmer necessarily occupies a central role in any discussion of the adoption of new technology. He ultimately decides on the use of a set of practices, thus is the protagonist of the drama. Agronomists, entomologists, extensionists, geneticists and economists all play supporting roles.

By tailoring technologies so that they fit farmers' purposes, agricultural scientists make it more likely that farmers will adopt them. Technologies which are not consonant with the farmers' circumstances are likely to be rejected. So it is that assumptions.. about farmers' purposes and circumstances are critical. The formulation of new technologies is guided by these assumptions.

The point of view taken in this discussion is that farmers are purposive in their behavior and are income-seeking risk averters, that they are sensitive to the nuances of their environment, and that they are reasonably efficient in managing the limited resources at their disposal. It is sometimes argued that culture and tradition play a large role in shaping farmer behavior, especially in developing countries. Our claim is that, while cultural elements may momentarily impede the use of a technology, the pull of economic forces will eventually dominate.

With this view of the farmer, those technologies which promise significant increases in profits at acceptable levels of risk will be adopted.

Promoting Change

With profits and risk aversion as the dominant elements shaping farmer response to technologies, there are two avenues for influencing change. One involves changing the environment so as to increase profits or reduce risks for given technologies. The second involves developing whole new technologies. Virtually all nostrums for promoting change can be grouped under one of these headings.

Environmental changes commonly recommended are those which facilitate access to information, to inputs, and to markets. These include extension work, credit programs, lower prices for inputs, effective distribution of inputs, guaranteed prices, storage programs, and market roads. Most of these measures can be directly influenced by government policy.

Developing new technology usually involves research. Work on varieties emphasizes grain type, susceptibility to disease and insects, maturity dates, storability, growth patterns, and responsiveness to management. Work on agronomic practices tends to focus on fertilizers and dates of planting.

It will be argued that making technologies profitable is the dominant factor in promoting change. As a corollary, when technologies fail in diffusion it is usually because they are not sufficiently profitable or are excessively risky. This might be because of farmer access to information, inputs or markets or it could be that the proposed technology is not effective in converting inputs to product. The ensuing discussion focuses on the latter. It points to the possibility that a major difficulty is in research methodology, i. e. that insufficient attention is given to farmer circumstances in developing and testing technologies.

The level of technology applied for the production of a given crop is partially determined by the consumption pattern of this crop. When looking carefully at consumption patterns of barley

one notices that the level of the technology used for production in countries where this crop is used for malting is different from that practiced in countries where barley is grown for animal feed or human use.

In countries where barley is grown for animal or human consumption one also notices that this crop is cultivated under harsh production condition i.e. less quality soil and less rainfall and poor marketing and infrastructural services. Since farmers are naturally income-seekers and risk averters, and barley is grown in highrisk areas, any barley improvement program should be concerned with yield stability which is dependent on the development of suitable agronomic practices. To be efficiently responsive to market demands improvement of barley production should be carried out through an interdisciplinary collaboration among agronomists, economists and other agricultural scientists. For example, if barley production is improved for malting purposes where consumption is expected to be on the increase, price fluctuation resulting from this improvement will not seriously affect farmers interest in the new production technology. However, if more barley is being produced in countries where the main barley consumption is for human diets, the expectation is that there will be drastic reduction in prices because of the limited demand for barley as human food. Here the increase in production may not necessarily be accompanied by increase in consumption, because as the data presented at this Workshop indicates, a small percentage of barley production is being consumed by people.

To promote adoption of technology related to barley production, research methods must be changed so that farmers' circumstances play a more central role in developing and evaluating alternatives. We have noticed, for example, that when comparing rates of adoption in cereal technology among many countries, sharp differences in these rates are evident among agro-climatic regions. It is probably true that institutional treatments, extension services, infrastructure, access to inputs .. are somewhat better from one country to another. In the main, the regional differences in adoption rates result from the relative stability of the technologies. Getting the technology right is the critical step in promoting technological changes.

There are evident patterns in adoption of improved varieties and fertilizers when farms are grouped in terms of agro-climatic region. Patterns for fertilizers also appear when farmers are grouped by size. The argument developed here is that these patterns can be explained in terms of profitability and risk without resorting to other explanations. Passing reference was made to other forms of analysis featuring many other variables. These larger models offered little insight into the process of diffusing technologies beyond that gained from the simple tables presented here.

Farmers quickly take up varieties which suit their purposes -- roughly 95 percent of Turkey's Mediterranean farmers were using HYV spring wheat only five years after introduction and over 70 percent of the farmers in Thrace reported using HYVs within three years after their introduction. Larger farmers are usually among the first to adopt with smaller farmers following quickly.

Fertilizers are taken up less quickly and tend to be used in lesser amounts than recommended. Farm size generally influences fertilizer use with smaller farmers usually applying less than do larger farmers in similar agro-climatic circumstances. These actions could be a consequence of differing access to credit and inputs, differing transaction costs, or differing sensitivity to risk between larger and smaller farmers.

What does all of this imply for those concerned with promoting widespread diffusion of new technology? They can influence farmer decisions by maintaining favorable price ratios and by insuring widespread access to inputs as well as to information, in brief by influencing the environment of the farmer. There are certainly cases where such efforts would foster more rapid diffusion of technologies. But the marked influence of agro-climatic factors in adoption makes it appear that policy makers' primary concern should be to insure that research efforts lead to the evolution of technologies which truly fit the needs of those farmers for whom they have the strongest sense of concern. This is the critical requisite. To do this, research must be organized so that farmers' circumstances play a more central role in developing and evaluating alternative technologies.

FACTORS AFFECTING FARMERS' ADOPTION OF NEW PRODUCTION TECHNOLOGY : CLUSTERS OF PRACTICES

Charles K. Mann, Ph D.*

Economists and agronomists by the nature of their professional training bring to any discussion of adoption of new practices two completely different points of view. The economist is trained to think in terms of marginal or incremental changes and resource scarcity; the agronomist with his emphasis on interactions among practices in terms of complete packages of practices. Thus the economist presses for analysis of the benefits and costs of individual practices and inputs while the agronomist argues the need for adoption of the whole package at one time to capture the effects of the interactions.

The economist's approach scares the agronomist to death partly because he visualizes 20x20 factor experiments; partly because it pains him to contemplate accepting a yield below what he knows is possible. The economist, steeped in his world of resource contraints and marginal analysis is equally skeptical of approaches requiring major change in numeroud inputs and practices at once, particularly if the new package is significantly more costly than current farmer practice. As a result, casual encounters between economists and agronomists generally end with each deciding that the other has no appreciation of the facts of life as regards the adoption of new technology.

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One of the strengths of the recent interdisciplinary approach of the international agricultural research institutes and of projects such as ours in Turkey is that the encounters between agronomists and economists are not casual but serious and sustained and directed toward a common developmental objective. Possibilities emerge for some sort of synthesis of approach.

Despite the economists' misgivings, the package of practices approach to extending new technology has much to commend it. It assures the capture of all interactions, it holds up for the farmer a clear model to strive for in the long run even if he cannot achieve it in the short run; it simplifies the extension task; it provides dramatic yield increases for full adoptors which can serve to motivate others. For all its advantage, however, when it comes to explaining farmer behavior the package approach has serious disadvantages. Looking at survey data in Turkey, it is hard to find many farmers in either the Coastal region (Mexican type wheat) or on the Anatolian Plateau who have adopted the complete recommended package, although many have adopted substantial parts of it. (Demir, 1976; Winkelmann, 1976) This is not to say that the approach is invalid, only that if we are to understand farmer behavior, it is necessary to disaggregate the package. (Winkelmann, for example, in his foreward to Demir, expresses the view that "differences in risk, expected income and cost of each element of technology are large enough to outweigh the effects of the interaction among these elements." p, vi)

In the package of practices recommended to the Anatolian wheat farmer there are a dozen or so individual elements which one might consider separately in analyzing farmer adoption. However, using the collaborative approach noted above the economist's urge to separate elements and the agronomist's urge to combine them can be moderated and some sensible, operationally significant, subsets of the practices can be defined. With such subsets ordered in an agronomically and economically logical progression, it is then possible to evaluate farmer adoption behavior against this theoretical model. Also if the elements of the package of practices can be grouped into relatively few, yet meaningful subsets, these can be explored further with manageable agronomic experiments. For ease of exposition we will refer to these subsets as "clusters" of practices within the complete package of practices. Bill Wright and I have had many discussions about both the ordering and grouping or clustering of practices for cases where the farmer either cannot or will not implement the package all at once. If he cannot do itall, what should he do first?

In the Central Plateau of Turkey bunt poses a serious threat to wheat. Given the large losses which can be incurred should the crop become infected, seed treatment can serve as relatively cheap insurance against serious risk. Viewing the farmer, to use Winkelmann's phrase, as an "income-seeking risk averter" one would expect widespread use of a practice which reduces risk of loss at very low cost. Moreover, because of the long-term educational program on seed treatment by the Turksih Ministry of Agriculture these benefits are generally well-known by the farmer. In view of both the high expected benefit/cost ratio and the widespread knowledge of this practive it is hypothesised to be the first practice in the package which a sequentially adopting farmer would use.

Turning to another relatively simple and low cost practice, sketchy but persuasive experimental data suggest that the use of herbicide to curb weed competition can improve yields dramatically even when otherwise traditional practices are used. In a small series of experiments on farmer fields Ms. Nedret Durutan at the Turkish National Wheat Research and Training Center found that applying herbicide to farmer's fields even under primitive levels of technology and thin soils increased yields 67% from 41 kg/da to 61 kg/da. Even though these yields are extremely low before and after, these results suggest a benefit/cost ratio for the herbicide of over three to one with 16 TL per decare expenditure on herbicide returning 55 TL worth of wheat. Other experimental data generated by Hepworth and Tezel for herbicide used with otherwise unimproved practices gave a benefit/cost ratio of 4.4 to one. (Mann, 1975) In any sequential application of the technology herbicide application probably should come very early in the sequence.

Serious phosphorous deficiency is a characteristic of the soils of Anatolia. Many years of fertilizer experiments have shown consistently high returns to phosphorous application. (For more detailed discussion on this point and a comprehensive list of references, see Wright, 1977) Therefore as our serially adopting farmer moves up the scale of technological sophistication, his next investment probably should be the application of phosphate fertilizer at time of seeding in the fall. In Anatolia, where grain drills are now fairly widely available, this fertilizer would be normally applied with a grain drill, although in some cases the fertilizer is broadcast.

It should be noted that the drill itself represents a major improvement in cultural practices over hand broadcasting, providing both substantial savings in seed cost as well as yield increases due to better stand establishment. While I know of no data on the effect of a

drill on yield knowledgeable observers believe it to be substantial. In any event, since we are seeking operationally useful groupings, we need not separate the drill from the fertilizer since according to the survey data analyzed subsequently in this paper, the two practices are usually associated. For the present purposes, it does not matter if this association is because of important physical interactions or because once one practice is adopted, the marginal cost of the other is low. Probably both reasons are important. In any event it seems reasonable to think of these two practices together as a cluster within the larger package of practices.

This concept of clustering takes on even more significance when our sequentially adopting farmer moves the next step up the technological scale. Up to this point, he has protected his wheat against bunt. At low cost he has eliminated weed competion as a threat to yield; he has removed the constraint of phosphorous deficiency. With these practices he probably still has not reached the yield ceiling of local improved varieties. Although chemical weed control has helped to increase soil moisture available to wheat, if he is to raise yields higher he must somehow further increase available soil moisture. To do this changes in tillage practices are needed for a fully effective moisture-conservation system. If added moisture can be conserved, another series of interactions are possible between nitrogen, moisture, and fertilizer responsive, high yielding varieties. Thus the final cluster of practices hypothesized is improved (and earlier) tillage for moisture conservation; added nitrogen which can be used effectively with this conserved moisture and high yielding varieties (HYV) which can respond to these high levels of nitrogen.(For details of recommended practices, see Wright, 1977.)

To summarize the argument to this point, in a serial or sequential adoption of practices, there is reason to believe that a particular ordering and grouping of practices would be logical and expected. These hypothesized steps are: (1) treatment of the seed against bunt, (2) 1+ herbicide use, (3) 1+2+ drill and fall phosphorous application, (4) 1+2+3+ moisture conserving tillage, nitrogen, HYV.

Having described this theoretical framework, let us examine the results of a 1976 survey of a random sample of Ankara province wheat farmers to see to what extent farmers follow such an ordering and grouping in adopting the improved wheat technology. The data used in this paper consist of descriptions of the practices in use on the fields of 158 farmers. In cases where two or more sets of wheat production practices were in use on a single farm, data were collected separately

for each set. In this way "fields" were sefined within each of which practices were uniform. On the 158 farms this gave 231 fields of which29 irrigated ones were disregarded for present purposes of dryland wheat analysis. (For technical reasons, atthis writing, it was not possible to analyze this data by farmer instead of by field.)

The data are arrayed in table 1 with the practices set out across the top in accordance with the order described above. The table shows percentages of the fields in which the various practices were employed. As was expected a high percentage of the seed was treated (92%), often treated in the village itself by simple methods. The percentage of fields with herbicide use is substantially lower (58%). While lower than fall fertilizer use, this is quite a high percentage, considering that until recently this input was neither widely understood nor widely available. Moreover, in line with the hypothesis that a sequential adopter might use herbicide wven before phosphorous fertilizer, it is interesting to note that of the 65 fields with no fall fertilizer 26 (40%) were treated with herbicide.

Looking at only those fields with spring fertilizer, the second line of the table discloses an interesting interrelationship. As noted earlier, if a farmer applies herbicide without fertilizer, he probably obtains substantial economic benefits from his investment. However, if there is good spring moisture and he applies nitrogen but no herbicide, profuse weed growth may occur. This result is suggested by the very high percentage (84%) of fields with spring fertilizer which also received herbicide. In fact, in the fields with spring fertilizer there was a higher incidence of herbicide use than any other single practice except seed treatment. Herbicide use was even more frequent than second tillage or even fall fertilizer.

These results suggest that to some extent (i.e. in a good rainfall year) farmers may have found the benefit of spring nitrogen to be independent of the rest of the practices of the moisture conservation cluster. The farmer may realize enough benefit in the good years to cover the loss due to wasted nitrogen in the bad, particularly if he can control weed growth. For this reason perhaps spring fertilizer should be considered as a separate "step" coming in sequence between the seeding cluster and the moisture conservation cluster.

Turning to tillage practices the fact of secondary tillage alone is not enough to qualify a field as having improved tillage. Particularly if done with a moldboard plow secondary tillage may do little to help conserve moisture. If only those fields are considered where second tillage was done by sweep this element of the moisture conservation cluster is found only on about 25% of the fields. The most widely practiced element within this cluster (not counting spring fertilizer) is the early plowing

of 27% of the fields (starting before May first).

On the basis of the cluster hypothesis it had been expected that selecting fields on the basis of tillage date could serve to separate those using the full package from those not using it. As can be seen from the break-out of early plowed fields, to some extent, this is the case. Early plowed fields do tend to have a higher percentage than late plowed fields of other practices such as fall fertilizer (85% in early, 61% in late); secondary tillage with sweep (49% in early, 15% in late); spring fertilizer (60% in early. 36% in late). Clearly practices on early plowed fields tend to be more improved than those on late plowed fields. However, whereas one would expect to see the full set of practices once the decision to plow early was taken, there are surprising gaps. As noted, only 60% of the early plowed fields received spring fertilizer and only 20% were planted with high yielding varieties (defined as Bezostaya or Bolal). (It should be noted that this is quite a restictive definition of HYV and excludes many local improved varieties capable of yielding quite well up to yield ceilings roughly double the national average. Thus until a farmer begins really to fine tune his practices, lack of an exceptionally high yielding variety may not be a serious constraint.)

Rather than reflecting some behavioral weakness in the model, this above result may stem from problems in the distribution of both seed and spring fertilizer. One expects a farmer both plowing early and using a sweep to know about spring fertilizer and improved varieties. We did hear a number of complaints about problems in finding fertilizer in the spring and about late seed delivery in the fall. A number of farmers were irate about seed deliveries in November after their planting was complete. In most cases, they simply sold the seed at a large discount. (Hopefully it stays out of the flour mills.) Accordingly, there is considerable risk in the use of the HYV's, not from the point of view of field performance, but timely delivery for planting. (This is true only in the first year of use, not in subsequent years when the farmer saves part of his own crop for seed.) New government measures are directed toward putting more HYV's in the farmers' hands but it is too early to assess the impact of these measures.

Since early plowing was not always found linked with all other elements of the package as hypothesized in a strictly serial adoption sequence, the data were "pivoted" about other elements of the moisture conservation cluster in the hope of finding some other element associated with full use of the package. In other words, maybe the only farmers who have it all together are those tilling with sweeps, or those doing three tillages, or those using HYVs. As can be seen from the table, none of these elements produce a row of 100% use of every practice in the package. However, this re-sorting does serve to highlight some

interesting points. In the fields growing HYVs and in field tilled with sweeps there is about the same relatively high percentage use of nearly all the elements in the package: early plowing, fall and spring fertilizer. The only major difference is the sharply lower percentage use of herbicide in the fields tilled with sweep plows (47% v. 84%).

All things considered, the fields with HYVs come the closest of any category to achieving the complete recommended package. However, as the bottom line shows, very few farmers have yet adopted the complete package. There are only two fields where the full package can be found, seven if variety and second tillage implement are disregarded.

Despite the fact that these results do not reflect perfection they do suggest that there has been substantial improvement in the cultivation of wheat in Anatolia. More specifically the survey data show that widespread use of both herbicide and spring nitrogen is comparatively recent. Simirarly there may be rapid adoption of HYVs as they become more available and better understood and as variety becomes more of a limiting factor under improving cultural practices. Already there are substantial numbers of early plowers and large number of sweeps and drills in use. Also notable is the high level of tractor use. In 65% of the fields all operations were done by tractor; even in those having some animal or hand operations over 90% of first plowing was done by tractor.

In interpreting the results of this survey, it must be remembered that it covers only Ankara Province, a relatively advanced part of Anatolia. Moreover, Ankara was the pilot province in the extension program for the improved wheat production package. Practices in other areas may lag substantially those reported here. In fact, even within Ankara province there are great variations by region. In several villages animal tillage and hand seeding are still the norm.

Returning to the pattern of farmer adoption of improved practices, the stepwise, sequential model of adoption does seem to have reasonable power in explaining how the improved wheat technology is being adopted in Anatolia. If it turns out that supply constraints explain the non-use of some parts of the moisture conservation cluster this model will be still more convincing. The model may also go some way toward reconciling the concerns of both the agronomists and economists. Modestly disaggregated into clusters within which important interactions are expected, both the physical and economic aspects of sequential adoption can be readily analyzed.

This method of analysis does not mean that the package approach must be dropped in the presentation of the technology to the farmer. It does suggest that if the farmer adopts technology this way, (regardless of advice to the contrary) then we should analyze it this way. With practices

ordered and appropriately clustered agronomic experiments of modest scope could help define the expected results of sequential adoption, could give some idea of the progression of yields and income changes which might be expected at each level of adoption. These experiments could be extended over different regions and weather years to assess how results and interaction differ by region and by weather. In this respect it might be useful to treat spring fertilizer separately since in some years it may be effective even outside the moisture conservation cluster and in other years ineffective without the cluster.

By way of suggestion, an initial experiment might take as treatments the following all with treated seed: (1) herbicide only; (2) 1+ seeding cluster; (3) 1+2+ spring N; (4) 1+2+3+ moisture conservation cluster, perhaps with and without HYV. (In view of the low use of HYVs it would be useful to see just what their impact would be where the farmer has nearly everything "right" except variety.) If the package is disaggregated in this fashion it captures considerable reality as to decisions facing the farmer while being manageable for agronomic experiments and economic analysis. For example, the major decision in adopting the moisture conservation package is the decision to "evict" the animals grazing the weedy follow and plow it early. Once that decision is taken, the other elements of the cluster are likely to be relatively easier to adopt particularly if input and equipment supply constraints can be removed.

When problems in the adoption of specific elements emerge, further experiments might be precisely tailored to explore possible reasons. For example, only one spike toothed harrow was found in the tillage of 202 fields,, yet it is part of the recommended package. An experiment on the package with and without this extra implement would show how much benefit from the package the farmer is losing by this equipment shortfall. If the loss is substantial efforts could be focussed toward increasing use of this specific implement.

One thing suggested by both this analysis and the interdisciplinary approach embodied in it is the need for constant feedback between farmer practices and research experiments. (On this point, see also Winkelmann, Plan Puebla, 1976, p 22.) Experimental design should yield data permitting economic analysis of major decisions the farmer faces. For example, a grain drill is relatively speaking an extremely expensive implement in Turkey. To buy or not to buy one is a major decision for a farmer, yet there is no research available upon which to base an economic analysis which could guide him. Of the grain drills, many are single box where fertilizer and grain are mixed. Is there enough added benefit from the twin box "combination" drill to justify it cost? We should

be able to advise the farmer on these bread and butter decisions. With the collaboration emerging between biological and social scientists within new research institutions perhaps before long we will be able to give such advice.

Breaking packages into a few operationally and agronomically significant clusters, a stepwise analysis reflecting how adoption is likely to occur would represent a major step toward helping a broad range of farmers. For example, as noted, recent research in Turkey suggests that just getting the small, poor, traditional farmer from step 1 to step 2 can increase his yield by over half. If he can do this several years in a row, he may be able to accumulate enough savings to buy fall fertilizr. Probably he could also fairly easily rent a drill. (On the subject of experiments designed to benefit the small farmer, it is interesing to note that research will start in 1977 in Turkey on an animal power version of the improved package to see what results are possible and also to demonstrate the need to change more than the power source if yields are to be improved.)

As to the relevance to barley of this wheat-oriented analysis, if a new barley research program is initiated the interdisciplinary approach could be built in from the beginning. Based on surveys of farmer practice, agronomic experiments paralleling likely farmer decision steps could be designed in addition to experiments aimed at fine tuning a package already advanced well beyond current farmer practice.

In conclusion we need not only research on where the farmer should be going but research on how he gets from where he is to where he should be. Many farmers have credit and resource constraints (not to mention a healthy skepticism) which prevent them from adopting a new package in a single step. Grouping the elements of the package into clusters seems to offer a manageable yet realistic way to approximate the farmer's decision path without sacrificing benefits of crucial interactions among practices. Being a result of agronomist/economist collaboration this approach should resolve some of the concerns of both. Most importantly, however, it offers to the farmers not only a description of his destination but a map on how to get there, complete with calculation of benefits and costs of both waystops and of the full trip.

To suggest providing such information about the ordering and clustering of elements within the package is not to suggest abandoning the package approach in carrying recommendations to the farmer. As noted earlier, this approach has much to commend it. With adoption of the integrated package remaining the goal, a more complete agronomic and economic analysis of how the pieces go together could assist farmers in attaining that goal.

REFERENCES CITED

Demir, Nazmi. "The Adoption of New Bread Wheat Technology in Selected Regions of Turkey", CIMMYT, 1976.

Mann, Charles K. "An Economic Analysis of the Benefits of Chemical Weed Control on Wheat in Anatolia" National Wheat Research and Training Project, Mimeo, 1975. (Published in Turkish by the Plant Protection General Directorate, Ministry of Agriculture)

Somel, Kutlu, "Economics of Improved Dryland Wheat Technology: A Case Study of Ankara, Turkey. (Unpublished, Ph.D Dissertation, Stanford University, February, 1977.)

Winkelmann, Donald L., "Promoting the Adoption of New Plant Technology" Paper presented to the World Food Conference, Iowa State University, June 1976. (CIMMYT Mimeo)

_____., "The Adoption of New Maize Technology in Plan Puebla, Mexico", CIMMYT, 1976.

Wright, Bill C., "Dryland Agricultural Cropping Systems in Low Winter-Rainfall Regions", Paper presented at An International Symposium on Rainfed Agriculture in Semi-Arid Regions, Riverside, California, 1977.

Table 1: Summary of Adoption of Selected Practices in Wheat Production in Ankara Province, 1975-76 Crop Year (158 Farmers)

			Seeding Cluster/1			Moisture Conservation Cluster						
	Treated Seed	Herbicide	Fall Fert.	Drill Seed	Plow Early	2nd Tillage Yes	2nd Tillage swp/3	3rd Tillage Yes	3rd Tillage swp/3	Spring Fert.	HYV	All operations by tractor
All Fields/2 (202 Fields)	92%	58%	68%	70%	27%	61%	(40%)	11%	(61%)	43%	12%	65%
Spring Fert. (86 Fields)	97%	84%	78%	71%	37%	73%	(48%)	16%	(50%)	100%	20%	63%
Plow Early (55 Fields)	100%	65%	85%	93%	100%	91%	(54%)	25%	(50%)	60%	24%	96%
Sweep 2nd tillage (25 Fields)	98%	47%	88%	94%	59%	100%	(100%)	29%	(50%)	65%	18%	90%
HYV (25 Fields)	100%	84%	92%	100%	56%	92%	(39%)	20%	(60%)	68%	100%	96%
3rd Tillage (23 Fields)	100%	52%	96%	91%	61%	100%	(43%)	100%	(61%)	61%	22%	78%
Complete Package (2 Fields)	100%	100%	100%	100%	100%	100%	(100%)	100%	(100%)	100%	100%	100%

/1 87% of fall fertilizer is applied by drilling with the seed.
/2 Excludes irrigated fields.
/3 Percentage of those doing 2nd or 3rd tillage who use sweep for that operation.
/4 If disregard variety and lack of sweep in secondary tillage there are7fields with complete cultural package.

WEED CONTROL

CULTURAL AND WEED CONTROL PRACTICES FOR BARLEY PRODUCTION IN NORTH AFRICA

By

W.L. Nelson*

Barley production in North Africa varies from 3,000,000 to 4,000,000 hectares each year. Morocco and Algeria account for 3/4 of the area. Barley is used mainly as animal feed, but in some areas it is consumed directly as human food. It is grown as a winter crop; however spring habit types are grown. F.A.O. production estimates for barley production in North-Africa are presented in Table 1.

Table 1. Summary of Barley area, production and yield in North Africa 1961-1971 with comparison to wheat yield.

Country	Area 1000/ha.	Production 100 tons	Yield tons/ha.	Yield Wheat tons/ha
Morocco	1815	1670	0,92	0,91
Algeria	745	459	0,62	0,63
Tunisia	411	112	0,27	0,47
Libya	340	93	0,27	0,25
North Africa	3311	2334	0,70	0,69

Source: F.A.O. Production Yearbook.

Barley production in North Africa ranks second to wheat. The amount of area planted to barley varies somewhat each year in response to weather conditions. Poor weather conditions at seeding favors increase in area seeded to barley. There is a trend to replace barley by wheat as new higher yielding wheat varieties and new production technology are introduced. Higher prices for wheat also encourage production of wheat. Increasing population pressure also causes a shift to wheat production in effort to reduce importation. As an example between 1971-1974 a 14% shift away from barley seeded occurred in Algeria. Yield also declined indicating that the shift occurred in the better land area.(2)

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Barley is usually concentrated in the lower rainfall regions and on the shallow more marginal land. Saari and Srivastava (1) argue that barley is more responsive per unit of available moisture than most crops in the Middle and Near East regions. The data are presented in Table 2.

Table 2. Comparison of the ratio of grain production of Barley and Wheat to reported moisture. Data from Regional trials 1975-1976.

Rainfall or irrigation reported in mm water (to nearest 100)	Kilograms grain per mm of water*	
	Barley	Wheat
<200	7,5	1,1
300	8,0	6,1
400	8,7	5,6
500	3,4	8,7
600	5,6	7,8
>700	4,7	11,6

As the rainfall increases or where irrigation is applied, this advantage for barley decreases and wheat yields become greater than barley. Saari and Srivastava also report that there is a great variation between different barley varieties or selections in each of the different rainfall regions suggesting that yield improvement is possible in both low and high rainfall areas. In Table 3 data from Algerian farmer demonstrations show similar yield variations between varieties and comparative yield with Siete Cerros.

Table 3. Average yield of Barley varieties grown in seven locations in 2 regions in field plots with comparative yield of Siete Cerros 1974-1975 Algeria.

Variety	Yield in Qx/ha.			Yield %	
	West	Central	Average	Barley Check	S.Cerros
Zemyr	48,8	22,5	35,7	121	192
Ager	42,6	24,1	33,4	113	180
Maguelone	42,1	24,5	33,3	113	180
Berenice	42,6	19,6	32,1	108	173
Clipper	42,3	24,5	31,0	105	167
Checks: (Saida)	34,6		29,6	100	159
(Tichedrott)		24,5			
Siete Cerros	22,8	14,4	18,6	-	100

Date from 1974-75 Annual I.D.G.C.-CIMMYT report, Algeria.

*Average mean yield of all entries in RBYT and RfWYT divided by the moisture available during the season (12 RfWYT and 21 RBYT locations)

The data from regional trials and the Algerian farmer demonstrations indicate yield variation and the ability of barley to produce high yields under adverse conditions. The high yield of barley in Table 3 as compared to Siete Cerros was mainly due to the rapid maturity of barley as compared to wheat. After April there was no appreciable precipitation. Barley was able to mature on moisture reserve, while wheat, with a longer maturation period, suffered severe drought stress.

The data presented in Tables 2 and 3 are not typical of the production conditions for barley in North Africa. Although the moisture levels and temperature conditions may have been representative, the land preparation and fertilizer level was not typical of barley production. Both the farmer demonstration trials and variety yield trials were grown under optimum fertility and with better than average soil preparation, with good weed control. These data are more representative of the yield potential of barley under good management. It will be noted that the yields reported are about 5 times the average yields reported in Table 1. This suggests some of the magnitude of response that good production management could give with the best varieties.

Supporting data from farmer demonstration trials in Tunisia during 1971-1972 and 1974 reported 101, 115 and 124% yield for Martin variety of barley as compared to INIA 66. Both wheat and barley were grown in the same trials under the best management practices. Tunisia also reported yields in the higher rainfall regions were generally about 70% of INIA 66 in 1973, and in all trials yielded 92% of INIA 66.

Barley production in North Africa could easily be doubled with improved management practices. That barley yields respond to good production management has been well demonstrated in comparative yield trials with wheat under the same improved cultural practices. North Africa could also increase barley yields by breeding varieties for specific regions and growing conditions.

To put into effect the needed improvement in barley production management will be more difficult than it has been for wheat productions. Most of the land in barley will not respond as well to improved practices as the better land in wheat production. Shallow soils and low erratic rainfall are common to the major barley growing regions. These soils have a low average yield potential even with the best management. In addition, traditional farming with animal power limits the amount of soil preparation and weed control before seeding. Most of the land must be prepared after the first rain which makes the date seeding highly variable. Although broad leaf weeds could be controlled by 2.4D, both the equipment and herbicide are not often available to the small farmer.

Cultural practices for barley production in North Africa are similar to those followed for wheat production in general, barley needs an application of 30 to 45 units of P_2O_5 per hectare. It responds to nitrogen in accordance to the rainfall and soil depth. Present varieties will lodge with levels of nitrogen for maximum wheat production in the higher rainfall regions. In the regions where most of the barley is produced, rainfall is limited so lodging is not a problem at the recommended levels of nitrogen for wheat in the same region.

The main problem of nitrogen fertilization is to balance the nitrogen needs with the available water. Shallow soils do not hold much water reserve. When the soil depths is less than 75 cm, summer fallow has little advantage for moisture storage. High summer temperature in much of the barley region also decreases the efficiency of summer fallow, and is particularly critical in shallow soils. Under these conditions, the application of nitrogen may not give good yield responses if rainfall is erratic or low.

The most reasonable recommendation for nitrogen application in these conditions is to apply the nitrogen in the tillering stage in years when favorable early rainfall fills the soil with good reserve. In dry years when little moisture reserve is present, the chance for a good nitrogen response is reduced. However, most of the production region has a low fertility level due to a long history of farming and heavy pasturing of stubble and weed growth. This limits the amount of organic matter returned to the soil, so most of the soils are very low in organic matter. Many soils have had extensive erosion further limiting fertility. Under these conditions a good response to nitrogen can be expected when rainfall is sufficient for effective moisture storage or when rainfall distribution is good throughout the growing season.

The control of weeds by 2 4-D, other herbicides, cultural management or by other means can be an effective stimulus to yield. Selective herbicide may be toxic to barley and not to wheat or the reverse situation occurs. For example, Suffix is effective for the control of wild oats in wheat but is phytotoxic to barley. Avenge will contrll wild oats in barley but is quite toxic to wheat. Dozenex causes more yellowing of barley than wheat, but apparently does little yield damage. The application of some herbicides needs much more technology than the current level of knowledge in barley production.

Table 4 shows that the yield of barley can be increased with weed control by herbicides. Wild oats were the most damaging species in these trials, so herbicides that controlled wild oats gave a good yield response. Early control of wild oats decreased competition favoring increased yield. Suffix controlled wild oats but damaged the barley resulting in no yield increase.

The 2, 4-D application controlled the broad leaf weeds but appeared somewhat toxic to the barley when applied in late shooting stage. Avenge appears to have good promise for wild oat weed control and is compatible with 2, 4-D general weed control.

Table 4. Affect of herbicide treatment on Barley with high density of wild oats, Algeria 1975-1976.

Herbicide	No Trials	Yield Q/ha			%	%weed control	
		Treated	Check	Increase	Increase	W.Oats	Dicotyledons
Avenge	2	21.6	12.9	8.7	67	95	0
Dicuron	1	13.8	9.0	4.8	53	60	60
Avenge + 2.4D	2	21.6	15.4	6.2	40	95	95
Dicuron + Certrol	1	23.7	18.0	5.7	32	90	90
Printan 22	1	21.0	18.0	3.0	17	50	85
Dozanex + TOK 50	2	24.9	22.5	2.4	11	90	90
Suffix	1	18.0	18.0	0	0	90	0
2.4-D	1	26.6	28.7	-2.1	-7	Tr.	98

Data 1975-1976 I.D.G.C.-CIMMYT Annual Report.

The future of barley production in North Africa depends upon several factors. As population pressure increases the increased food demands may shift more land to wheat production. Demands for all cereals will increase as living standards improve causing increased demands for animal production. Since water for irrigation is limited, animal feed will have to be produced on rainfed land. Barley is the most efficient cereal for a source of animal food concentrate in the low rainfall areas. Improvement in both cultural practices and varieties can double barley production even in the low rainfall regions.

What can be done to improve cultural practices ? With traditional farming, improvement will be slow. Unless better equipment is made available for animal power, or the land comes under more mechanized farming, there will be little improvement in seed bed preparation or seeding technics. Increased fertilizer use with financial assistance will

increase production. However, without better weed control increased use of nitrogen will be less effective. The use of 2.4-D with back-pack sprayer is practical on small farms and on steep hillsides often planted to barley. The use of other herbicides will depend upon the cost and flexibility of their use. Herbicides that require very accurate rates to prevent damage are not practical for hand sprayer applications.

On the larger farms most often using tractors for land preparation, barley will respond to the same good cultural practices that increase wheat yields. This includes good seed bed preparation and preplant weed control when possible. Seeding should be done with a well adapted mechanical seeder for uniform stands that can complete with later germinating weeds. An adequate weed control program with herbicides and a fertilizer program adapted to the available water supply are necessary for maximum production.

In North Africa, barley varieties with a medium maturity range have the best potential. The present varieties have a long vegetative stage and short maturation period. The usual practice is to seed barley earlier than wheat. The barley developes a heavy vegetative growth and heads just before wheat. The rapid early growth makes it more competitive to the weed growth than wheat. After heading the barley develops much more quickly than wheat. Very early varieties are subject to frost damage in higher elevations, but when seeded late early varieties are needed to mature before the high temperatures. Short duration varieties will normally yield less, but may yield more than later maturing varieties when planted late. Two types are needed. One for seeding early to take advantage of a long growing season when the rainfall begins early or a variety that can be seeded late and develop rapidly during a short growing season. This would better utilize the available moisture.

All of these factors will require greatly increased extension to the farmers Farmers must be informed on better land preparation technics, mechanical seeding,more and better use of fertilizer and better use of fertilizer and herbicides and the specific characteristics of barley varieties. Adequate seed and financial aid must be available. It does no good to have only late varieties available adapted to early seeding when seeding is late, or only early varieties, for early seeding.

Extension of information to farmers is extremely difficult in North Africa. The major effort has been in the more highly mechanized farming on the more productive land. The small farmer on the poor land normally growing barley has not been reached. If progress in barley production occurs, it will be largely on the small farms where most of the barley is produced.

References

1. E.E. Saari and J.P.Srivastava -
Improvement and Stabilization of Production of Winter Cereals: Potentials in a Single Crop Septens, Middle East and African Seminars, Tunis, Tunisia, 1977.

2. 1974 - 1975 I.D.G.C./CIMMYT Annual Report, Algeria.

3. 1974 - 1975 CIMMYT Annual Report, Tunisia.

4. 1973 - 1975 CIMMYT Annual Report, Tunisia.

5. 1975 - 1976 I.D.G.C./CIMMYT Annual Report, Algeria.

WEED CONTROL IN WHEAT AND BARLEY IN THE MIDDLE EAST

By

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Summary

Wheat and Barley constitute the bulk of agricultural production in the Middle East. Unfortunately, these crops are grown on marginal soils which are infested with annual and perennial weeds. The principal weed species include Avena sterilis, Convolvulus arvensis, and Sinapis arvensis. It has been estimated that yield losses due to weeds are between 20-30%.

Most of the weed control practices involve hand pulling, hoeing or mechanical tillage. The use of herbicides is limited to about 2-5% of the cereal area. The chemicals used are mostly 2, 4-D with a few applications of barban.

With the increasing cost of agricultural labor and its decreasing availability, it has been suggested that herbicide application should be more widely used in the Middle East. In addition to the spraying of the economical phenoxy herbicides, mixtures with benzonitriles and dicamba should be used to widen the spectrum of control of broadleaved weeds. Glyphosate may be used after grain harvest for the control of perennial weeds. For the control of wild oats and other grasses, triallate, chlortoluron and others listed in the manuscript may be used. It is now advisable that plant breeders should study the genetic response of newly developed varieties to the most widely used herbicides.

Introduction

Wheat and barley are considered as two of the major food and feed crops of the world. In the Middle East, wheat constitutes the basic diet of the population; whereas barley is consumed by cattle, sheep and poultry. Both crops are adapted to a wide range of soil and climatic conditions.

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Although these crops make up the bulk of agricultural production in the area, they are grown on poor marginal soils which are inadequately planted and fertilized, and are hampered by fluctuations in rainfall and periodic drought as well as weed infestations. All these factors share the responsibility for reducing the potential yield of these crops.

Weed Flora

Wheat and Barley are most often infested with annual broadleaved weeds. The principal weed species include Anthemis cotula, Capsella bursapastoris, Carthamus oxyacanthus, Cephalaria syriaca, Cirsium acarna, Polygonum aviculars, Raphanus raphanistrum, and Sinapia arvensis. The most widely spread annual weed in the Middle East is Sinapis arvensis, with Carthamus being very common in Northern Iraq. Of the perennial broadleaved weeds, the following species are prevalent: Cardaria draba, Convolvulus arvensis, and Leontice leontopetalum. The latter specie is extremely serious in Northern Bekaa, Lebanon. Two important perennials which infest cereal fields of Iran are Alhagi maurorum (camelsthorn) and Glycyrrhiza glabra (Liquorice). In Jordan, Prosopis farcta infests some of the wheat fields in the Ghor area.

The most serious annual grass weed in the Middle East is Avena sterilis. Others which may cause serious losses include Bromus tectorum, Lolium temulentum, Phalaria paradoxa, and Setaria viridis. From the perennial grasses, Cynodon dactylon may be a problem in some areas planted to wheat and barley.

Losses Due to Weeds

Weeds compete with wheat and barley for light, moisture and nutrients, particularly nitrogen. Such competition has increased with the use of dwarf varieties. The cereals are most sensitive to weed competition in their early stages of growth (i.e. between the 3-6 leaf stage). Data in Table 1 show that maximum weed competition in wheat occurs at the 5-leaf stage.

The classical work of Pavlychenko demonstrated the impact of early competition of wild oats on cereals. He found that Avena spp. exerted an irreversible damage on cereals during the first 20 days which resulted in reduction in yield (WSSA Newsletter, 1977).

Table 1. The effect of weed competition on the grain yield (kg/du) of wheat at various stages of growth.*

Treatment	STAGES OF GROWTH OF WHEAT 'NAJAH'					
	3-leaf	5-leaf	Jointing	Anthesis	Soft Drought	Ripe Grain
Hand weeded	370	396	389	392	320	316
Unweeded	328	327	325	327	322	321
% Loss in yield	11.1	17.5	16.5	16.6	-	-

* Part of data published by Saghir and Aqiqullah (1970).

There have been very few weed competition studies conducted in the Middle East. It has been estimated that losses of wheat yield due to weeds amounted to 45% in Iraq (Al-Qaisi, 1972), and 20% in Turkey (Hepworth and Tezel, 1975). In Jordan, the estimate is between 30-60% (Aresvik, 1976); whereas in Lebanon the loss was 7% and 17% for barley and wheat, respectively. (Saghir and Aqiqullah, 1970). Nelson (1975) reported an average loss of 19.4% in 13 countries of North Africa and the Middle East. This amounts to about 5 million tons of wheat lost due to weeds. For comparison purposes, the loss in the United States is estimated to be 14% for barley and 13% for wheat (Crafts and Robbins, 1962). Parker and Fryer (1976) estimated crop losses due to weeds in the U.S.A. to be between 5-15%, depending on the crop and the state, with a 5% figure to be a reasonable estimate for the most highly developed production areas.

In addition to crop losses, weeds harbor disease organisms and insects. They interfere with harvesting operations, particularly in the case of climbing weeds such as Convolvulus arvensis which may cause lodging of the cereals, thus affecting harvesting. Al-Qaisi (1972) reported that weed seed of Avena, Cephalaria and Sinapis species, when mixed with wheat grains, resulted in dark coloured flour which was bitter and had a bad odour. Some weed contaminants may also cause a laxative effect when mixed with wheat flour. Al-Fakhry et al. (1971) found that wheat and barley grains marketed in Iraq are of 83-87% and 90-93% purity, respectively, as compared to the international standard of 96% purity from weeds.

Extent of Weed Control Practices

Most of the weed control practices in the Middle East involve hand pulling, hoeing, or mechanical tillage during the fallow season. In wheat and barley, weed removal is delayed until the weeds are well developed in order to use them for livestock feed. Unfortunately, this practice causes serious reductions in crop yield because critical weed competition occurs at the early stages of cereal growth. As the costs of agricultural labor increase, and as their availability decreases, farmers are moving cautiously to the use of herbicides for weed control in cereals. In the region of North Africa and the Middle East, it is estimated that only 5% of the wheat area is sprayed with phenoxy compounds (Nelson, 1975).

Weed control research in Lebanon started by the author in 1959 at the American University of Beirut. In a study conducted on the tolerance of wheat and barley to 2, 4-D sprays at different stages of growth (Saghir and Aqiqullah, 1970) it was found that the herbicide caused injury when applied at the 3-leaf stage; whereas at the 5-leaf, jointing, and booting to heading stages only high concentrations above 2.0 kg/ha (a.e.) were phytotoxic. At the 5-leaf stage, a highly significant increase of 19% in the grain yield of barley was obtained at the 1.0 kg/ha as compared to the unweeded check. The protein percentages of wheat and barley seeds were significantly increased as a result of the application of 2, 4-D at rates above 2 kg/ha; however, significant reductions in the total protein yield of the two crops were observed at these treatments. No real effect was found on the amino acid composition of the grain protein from wheat and barley treated with 2, 4-D (Pellett and Saghir, 1971).

In Lebanon, about 5% of the pesticides imported are herbicides, with 2, 4-D being the principal chemical used on cereals. It is estimated that out of the 764,000 dunums of wheat and 135,000 dunums of barley planted in Lebanon (Aqiqullah, 1968), about 52,000 dunums have been sprayed with 2, 4-D . This amounts to 5.7% of the area planted to cereals (USAID Report, 1972).

In Jordan, weed research started in 1968 on wheat. As a result, 2, 4-D has been sprayed on 20,000 dunums in 1972 and about 33,500 dunums in 1976 (which amounts to 1.6% of the wheat area). About 400,000 dunums are still weeded by hand (Table 2).

It has been found that chemical weed control is very economical to use since the application of 2, 4-D costs 250-300 fils/du whereas handweeding costs 1000-1250 fils/du (1$=333 fils) (Aresvik, 1976).

Table 2. Weed control practices in the different wheat regions in Jordan*

Wheat Region	Annual Rainfall (mm)	Total Area (dunums)	Average Yield (Kg/du)	Hand Weeding (%of Area)	Herbicide (% of Area)
Desert area	150-250	400,000	41	None	None
Eastern area	250-300	700,000	64	10	1
Western plain area	300-400	600,000	92	20	4
Upland area	400	180,000	105	Mostly	Little
Ghor area	Irrigated	50,000	130	95	5

The projected yields of wheat and barley for Jordan, based upon the adaptation of improved cereal technology and particularly the use of herbicides, are shown in Table 3. It is estimated that the target yield of wheat for 1980 shall reach double the present yield, and that of barley shall increase by about 50%.

Table 3. Projections of wheat and barley yields in Jordan (kg/du)*

Crop	Present Yield	Potential Yield	Target 1980	Yields 1985
Wheat (rainfed)	70	180	150	160
Wheat (irrigated)	150	500	300	400
Barley (rainfed)	70	150	100	130

* Compiled by the author from Aresvik, 1976.

In Iraq, handweeding is practiced on private farms. The first use of 2, 4-D on wheat and barley has been reported by Tammimi and Hassawy (1965). After 1967, the Weed Control Department had recommended the spraying of barban and 2, 4-D (sodium or ammonium salts) for the control of wild oats and broadleaved weeds in cereals, respectively, on government farms (Al-Qaisi, 1973). Such large scale spraying has largely been accomplished by aerial applications in Northern Iraq.

In Turkey, Hepworth and Tezel (1975) reported that a research and demonstration program in weed control was initiated in 1950. The areas sprayed with phenoxy herbicides had increased from 1,350 hectares in 1953 to 800,000 hectares (about 10% of the wheat area) in 1973. In 1975 the area treated had declined to about 3-4% due to the high prices and short supplies of the herbicides.

Weed Control Suggestions

In addition to the preventive methods of weed control such as the use of clean seeds, adapted varieties, proper seed bed preparation and crop rotations, weeds may still be sufficiently troublesome to justify the use of chemical weed control. The cheapest chemicals to use for the control of annual and perennial broadleaved weeds are the phenoxy herbicides. The principal chemicals used amongst this group are 2, 4-D, MCPA and their combinations. It is preferable to use either the amine salts or the low volatile ester formulations to cut down on drift which may affect sensitive crops. Wheat and barley are susceptible to these hormone-type herbicides between the time of germination and tillering, as well as during the early boot stage.

In the case of weeds tolerant to the phenoxys such as *Anthemis* and *Polygonum* species, benzonitriles such as Bromoxynil and Ioxynil could be used. In order to broaden the weed control spectrum in cereals, mixtures of phenoxys with benzonitriles, or dicamba (only for wheat) could be used. For the control of the perennial weed, *Convolvulus arvensis*, sub-surface layering of trifluralin after small grain harvesting proved to be effective. For *Cirsium*, foliar applications of atrazine is useful. For *Cinodon dectylon* as well as other perennial weeds, glyphosate applied after grain harvest is very effective.

With the continuous use of herbicides for the control of broadleaved weeds, it has been observed that grass weeds have become a problem in cereal crops. Sellami (1975) estimated yield loss from grasses to be 4-6 times greater than from broadleaves. One of the most serious grass weeds in wheat and barley is *Avena sterilis*. Many herbicides have proved to be effective for wild oat control. These include triallate as pre-plant incorporated treatment; and barban, benzoylprop-ethyl (for wheat), flamprop-isopropyl (for barley) and triallate granules as post-emergence application. Other experimental wild oat herbicides include difenzoquat and flufenprop methyl (SD-29761).

For other grass weed control in cereals, it is possible to use pre-emergence applications of chlortoluron, methabenzthiazuron, metoxuron, notrofen, terbutryne, and trinulan. An experimental herbicide for grass weed control in cereals is dichlofop-methyl. With the increased use of herbicides in improved cereal technology, it is advisable that plant breeders should consider the genetic response of new germplasm to the most widely used herbicides before releasing their new varieties to farmers.

REFERENCES

AL-FAKHRY, A.K., HASSAN, S.A. and AL-DOORI, A.H. (1971). Grading quality and marketing of wheat and barley in grain markets of Ninevah. Mesopotamia Journal of Agriculture 6:81-90.

AL-QAISI, K.M. (1972). Weeds and their control (in Arabic). Bulletin 62, Directorate of Field Crops. Ministry of Agriculture, Baghdad, Iraq.

AL-QAISI, K.M. (1973). Weeds of wheat and their control by herbicides (in Arabic). Bulletin 73. Directorate of Field Crops. Ministry of Agriculture, Baghdad, Iraq.

AQIQULLAH (1968). Tolerance of wheat and barley at different stages of growth to 2, 4-D sprays. M.Sc. Thesis, American University of Beirut, pp.70.

ARESVIK, O. (1976). The Agricultural Development in Jordan. Praeger Publishers, New York, pp. 375.

CRAFTS, A.S. and ROBBINS, W.W. (1962). Weed Control, McGraw-Hill Book Company, New York, pp.660.

HEPWORTH, H.M. and TEZEL, C. (1975). Weed Control on the high plateau of Turkey. Third Regional Wheat Workshop Proceedings, Tunisia: 186-191.

NELSON, W.L. (1975). The weed situation in the regions of North Africa and the Middle East. Third Regional Wheat Workshop Proceedings, Tunisia: 178-183.

PARKER, C. and FRYER, J.D. (1976). World Crop Losses from Weeds. FAO Plant Protection Bulletin 23 (3/4): 83-95 (PANS 22(3): 415).

PELLETT, P.L. and SAGHIR, A.R. (1971). Amino Acid Composition of Grain Protein from Wheat and Barley Treated with 2,4-D. Weed Res. 11(2/3)182-189.

SAGHIR, A.R. and AQIQULLAH. (1970). Tolerance of Wheat and Barley at Different Stages of Growth to 2, 4-D Sprays. PANS. 16(2): 336-342.

SELLAMI, A. (1975). Experimentation et demonstration dans le domaine due desherbage chimique en Tunisie. Third Regional Wheat Workshop Proceedings, Tunisia: 193-202.

TAMMIMI, S.A. and HASSAWY, G.S. (1965). Weed Control by 2,4-D in Wheat. Bulletin Biological Research Centre, Baghdad, Iraq. 1:63-70.

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT (1972). Crop Protection In The Mediterranean Basin, A multi-disciplinary study team report, pp.78.

WEED SCIENCE SOCIETY OF AMERICA NEWSLETTER. (1977). A Bit of History. 5(1): 1-12.

DISEASES

THE BARLEY DISEASE SITUATION IN THE NEAR EAST WITH SPECIAL REFERENCE TO SOURCES OF RESISTANCE

By

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In the Near East Region barley is attacked by several diseases and some of them are serious and cause considerable losses to yield.

The following diseases and causal organisms were reported in different countries of the Near East and their distribution is indicated in Table 1.

1. Rusts
   Leaf rust (*Puccinia hordei* Otth.)
   Stripe rust (*Puccinia striiformis* West.)
   Stem rust (*Puccinia graminis tritici* Eriks. and Henn.)

2. Helminthosporiosis
   Net blotch (*Helminthosporium teres* Sacc.)
   Spot blotch (*Helminthosporium sativum* P.K. et B.)
   Stripe disease (*Helminthosporium gramineum* Sacc.)

3. Smuts
   Covered smut (*Ustilago hordei* (Pers) Lagerh.)
   Loose smut (*Ustilago nuda* (Jens.) Rostr.)

4. Powdery mildew (*Erysiphe graminis* DC. f. sp. *hordei* Em. Marchal)

5. Septoria leaf blotch (*Septoria passerinii* Sacc.)

6. Leaf scald (*Rhynchosporium secalis* Oud.)

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Barley Disease Situation in Egypt

Leaf rust of barley is one of the important factors influencing barley production in the northern areas of the Delta. It is wide spread in this region where high humidity favours the development of the disease. Considerable losses in yield and deleterious effect on quality of grains can occur in some years.

Race surveys started in Egypt in 1967 and revealed the presence of ten physiologic races (2, 8, 14, 21, 23, 30, 32, 43, 46 and 51). The most common and widely distributed races were 2, 21 and 14 and constituted 29.6, 22.2 and 14.8 percent of the total number of isolates respectively.

The economic control of the leaf rust is through the use of resistant varieties. More than 10,000 barley cultivars and lines including the World Barley Collection, local promising varieties, lines of the Composite Cross and the USDA and FAO collections have been evaluated. Among the varieties tested only 1063 were highly resistant and out of these 21 varieties were nearly immune. Under Egyptian conditions it was observed that leaf rust resistance has been found in both six-rowed and two-rowed groups. The highest type of resistance and the greatest percentage of resistant cultivars were found in the material introduced from Asia and Africa.

Owing to the frequent and severe losses, there is a trend in the direction of employing chemicals to combat the rust organism on barley. During 1974 and 1975 seasons, trials for controlling leaf rust by fungicides were conducted by using Plantvax: (2.3-Dihudro-5 carboxanilido-60 methyl 1-1, 4 Oxathiin, 4,4-dioxide), at the rate of 0.4%, BAS 3050 F. (75% 0-Methyl benzoic acid anilide), 0.2%, Saprol (N,N^1-1,4-piperazomediyl-biz 2,2 2 trichloroethylidene-bisformamide), 0.2% and Indar (RH-1241): 4-n-buty 1-1,2,4-trizole), 0.3%, sprayed once when rust first appeared or twice: one at the first rust development then two weeks later.

The results obtained in 1974 showed that Saprol and Indar (RH-124) reduced rust infection from 50% in the control to 20.5% and 25.5% severity respectively in the sprayed plots. The resulting respective increase in grain yield was 29% and 25%.

Similar results were also obtained in 1975. Although one spray with these two fungicides gave satisfactory control, two sprays with an interval of at least two weeks was also profitable. Spraying should be started just before or at the time of rust appearance.

Barley is also attacked by stem rust, however losses caused by this disease are negligable From a total of 252 barley varieties and lines, they were tested at five locations representing different climatic conditions, 97 cultivars and lines showed good resistance to this disease.

Barley is mainly attacked by three species of the genus, Helminthosporium. Although a considerable effort has been made in developing resistant varieties, great losses often result from these serious diseases which influence both the yield and quality of grain.

The severity and prevalence of net blotch disease suggests that it is one of the important diseases of barley in Egypt especially in the northern areas of the Nile Delta. Losses due to this disease are estimated at about 10% in grain yield.

The most practical method for controlling this disease is to incorporate gene(s) for resistance. Screening the world barley collections for net blotch in Egypt showed that 1190 cultivars and lines maintained a sufficient level of resistance. Out of these varieties, 180 were highly resistant. These varieties were found in the material introduced from a number of countries.

Recent surveys have revealed that net blotch was less distributed in comparison to spot blotch, while stripe disease was widely distributed for the first time especially in the northern provinces of the Nile Delta on most of the local varieties.

Screening for disease resistance included 2646 varieties and lines mentioned before. Varieties showing resistance to both diseases in field trials were tested to spot blotch in the laboratory by using the detached leaf method described by Rapilly and Bonchet (1962) with some modifications.

Rigid screening resulted in the elimination of susceptible types during four seasons of testing. Only 82 varieties (51 of 6-rowed and 31 of 2-rowed group) proved highly resistant and could be recommended as sources of resistance.

Covered smut is an important disease because of the continuous use of infested barley seeds. The percentage of infection ranges from traces to 5% according to seed infestation, soil temperature and moisture. The annual losses are estimated at about 1 to 2% of the total yield. Seed treatment and the use of covered smut-resistant varieties are the combined methods of control.

Race surveys proved the existence of 16 physiologic races of Ustilago hordei in Egypt. Race 1 was predominated with 34.7 percent of the total isolates, next was race 14 (18.7%) followed by races 3 and 8 (both with 9.3%).

A total of 457 barley varieties and lines were tested for their reaction to this disease and 262 varieties and lines were completely free from smut.

In tests conducted over a period of seven seasons, twenty fungicides were tested to study their efficiency in controlling this disease. The fungicides, Dexon, PCNB, Spergon, Agallol and Brassicol are effective in controlling this disease and had no deleterious effect on seed germination.

Powdery mildew is a chronic disease which is now fully recognized as the cause of major yield losses in many parts of the world. In Egypt, it was apparently unimportant until 1967 when most of the foreign and local varieties were severely attacked.

The varietal reactions of barley cultivars tested in Egypt during 1973-75 indicated that 80 varieties and lines among 316 varieties tested at 6 localities exhibited high levels of resistance.

The use of effective fungicides is of interest in spite of the existance of resistant cultivars. In trials carried out during 1973-75, four fungicides, Ethirimiol (5-n-butyl-2-ethylamino-4-hydroxy-6-methyl pyrimidine) at the rate of 0.1%, Calixin (2,3-

Dihydro-5-carboxanilido-6-methyl-1-1, 4-oxathiin-4, 4-dioxide) at 0.1% Saprol (0.2%) and Plantvax (0.4%) were tested to study their protective and eradicative effects in controlling this disease. The results showed that two sprays of Ethirimol reduced mildew by 50% followed by Calixin (39.4%) in comparison with the untreated plots. By using these antimildew fungicides, yield was significantly increased, 23 and 17.5% respectively.

Conclusions

It is obvious from the data collected that a number of sources of resistance to individual diseases are available. Out of 11,000 barley varieties tested 25 were highly resistant to the three major diseases attacking barley (leaf rust, net blotch, powdery mildew and can be recommended as good sources in breeding for resistance to these diseases (Table 2).

TABLE 1. The reported distribution of barley diseases in the Near East.

Country	Disease Present+										
	Rusts			Helminthosporium			Smut		Powdery	Scald	Sep-
	Leaf	Stem	Stripe	Net	Spot	Stripe	Loose	Covered	Mildew		toria
Cyprus	+			+			+		+		
Egypt	+	+	+	+	+	+	+	+	+		
Ethiopia	+	+	+	+				+		+	
Iran	+	+	+				+	+	+		
Iraq	+					+	+	+	+		
Kenya	+	+	+	+			+	+		+	
Lebanon	+		+			+	+		+		
Libya	+	+	+	+	+	+	+	+	+	+	+
Pakistan	+	+	+	+	+		+	+			
Saudi Arabia	+		+	+		+	+	+	+		
Sudan				+		+	+	+	+		
Syria	+		+	+			+	+			
Turkey				+		+	+	+	+	+	+

Table 2:

List of barley varieties found resistant to leaf rust, net blotch and powdery mildew under heavy infection in Egypt.

Variety	C.I.No.	Source	Variety	C.I.No.	Source
San Carlos DIV. 5000	11533	Argentina	Peru	653	Peru
Anoidium x Rabat, a-4805-9-8r	11540	Canada	Hail's Hanna	682	Germany
La Estanzula 75 x Reka 1	11800	England	Peruvian	2441	N. Africa
Forrajera Klein x Reka 7	11800	England	Palmella Blue	3609	Egypt
Perolina	11805	England	Aim	3737	Egypt
Union	11807	England	Delta	4251	Egypt
Athenais		Cyprus		4976	Morocco
Herta		Holland	Cebada Capa	6193	Argentina
Local Marsa Matrouh		Egypt	Psaknon	6305	Australia
Composite Cross-line 205			Forrajera PM 85 DIV. 2383	8158	Argentina
Composite Cross-line 243					
Composite Cross-line 612			Forrajera De Invierno	8159	Argentina
			Traill	9538	USA ND
			Larker	10648	USA ND

References

Abdel-Hak, T. and E. Ghobrial, 1968. Studies on the control of covered smut of barley, Ustilago hordei (Pers.) Lagerh. in UAR. Min. of Agric. Tech. Bull. No. 9.

Abdel-Hak, T. and E. Ghobrial, 1968. Sources of resistance to leaf rust of barley, Puccinia hordei Otth. in UAR. Min. Agric. Tech. Bull. No. 11.

Abdel-Hak, T., Dessouki, S.M., Ghobrial, E., Mansour, A.A. and M.I. Khalifa, 1968. Sources of resistance to net blotch. Helminthosporium teres (Sacc.) in UAR. Min. Agric. Tech. Bull. No. 10.

Abdel-Hak, Ghobrial, E. and T. Sabet, 1975. Physiologic races of Puccinia hordei Otth., the casual organism of leaf rust on barley in ARE. Agric. Res. Review, Min. Agric. Vol. 53.

Abdel-Hak, Ghobrial, E. and T. Sabet 1975. Physiologic races of Ustilago hordei (Pers.) Lagerh., the casual organism of covered smut of barley in ARE. Agric. Res. Review, Min. Agric. vol. 53.

Abdel-Hak, Ghobrial, E. and T. Sabet. 1975. Studies on the control of covered smut of barley, Ustilago hordei (Pers.) Lagerh. in ARE. Agric. Res. Review, Min. Agric. Vol. 53.

Anonymous, 1969. FAO Information Bulletin of the Near East, Wheat and Barley Improved and Production Project, vol. 6, No. 1.

El-Zayat, M.M., Abdel-Hak, T., Mohamed, H.A. and M.M. Ben Halim. 1975. Present Status of cereal diseases on the Libyan Arab Republic, vol. 3, No. 1.

Ghobrial, E., Morsi, L.R. and T. Sabet, 1976. Sources of resistance to leaf rust of barley, Puccinia hordei Otth. in ARE. Second Congress of the Egyptian Phytopathological Society, Cairo.

Ghobrial, E., Hammouda, A.M., Abdel-Khalik, R. and E.E. Mostapha, 1976. Sources of resistance to Helminthosporiosis of barley in ARE. Second Congress of the Egyptian Phytopathological Society, Cairo.

Ghobrial, E., Hammouda, A.M., Abdel-Khalik, R. and E.E. Mostapha, 1976. Chemical control of leaf rust of barley. Second Congress of the Egyptian Phytopathological Society, Cairo.

Ghobrial, E., Hammouda, A.M. Abdel-Khalik, R. and E.E. Mostapha, 1976. Studies on the control of powdery mildew of barley in ARE. (Unpublished data).

Martin, H.E. 1971. List of Plant Pests and Diseases of Saudi Arabia. Report of FAO Plant Protection Division.

Mathur, R.S. 1968. The fungi and plant diseases of Iraq. (Unpublished report).

Morsi, L.R., Mansour, A.A., Khalifa, M.I. Ghobrial, E. and T. Sabet, 1975. Sources of resistance to net blotch of barley, Helminthosporium teres (Sacc.). Agric. Res. Review, vol.53.

Rapilly, F. and J. Ponchet, 1962. The use of explants of Gramineae for the study of the genus Helinthosporium Link. C.R. Acad. Agric. Fr., 48: 390-392.

BARLEY DISEASES AND THEIR SURVEILLANCE IN THE REGION

By

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The geographical area in which barley is grown coincides with that of wheat. However, it is often sown on the more marginal lands or in the lower rainfall areas. The cultivation of barley also extends beyond the normal wheat growing range. This is especially true when one considers latitude or elevation. In extreme polar latitudes or at high elevations barley has a distinct advantage. Part of the explanation may be the productivity in relation to the available moisture. We are aware that barley often produces more kilos of grain per mm of rainfall than most wheat varieties when the annual precipitation is less than 400-500 mm. (See Table 1). The lower rainfall and drier atmospheres also minimizes the disease production hazards but introduces other production instabilities.

Another area which may contribute to the advantage of barley in polar and higher altitude areas may be its productivity per unit time. An even more important feature may be its possible productivity per unit of heat. This feature should be considered in calories produced per kilo-calories of available energy as a measure of productivity.

Barley in the Middle East area of the world is of particular interest because a large portion of the production is still consumed directly by man. In this cradle of civilization barley was also one of the first food crops domesticated. Another interesting feature is represented by the fact that the primary center of origin and diversity for the species Hordeum is located in the Middle East. Unfortunately, the exploitation of this variability has not been as intensive as in some of the other cereal crops.

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The greatest use of the available barley germplasm has occurred in Australia, Europe and North America. The value of this germplasm speaks for itself because no natural variation exists in these areas. The successful cultivation of barley, however, has required the solving of a number of specific problems. Frequently, the problem was a serious disease situation.

The success of a varietal improvement programs can be measured in a number of ways, such as average yields of the area or by the expression of desired characters in a variety. The minimizing of losses due to diseases through incorporating resistance is also one such measure. The identification and incorporation of disease resistance has been a major contributor to varietal development in many countries.

Contrast this with the Middle East barley acreage. By and large the unimproved cultivars occupy the major acreage. They possess specific adaptation for the immediate area, but when you move these cultivars to a more favorable environment often an important component will be lacking. The missing factor all too often is an inadequate level of disease resistance. Because barley has been generally grown in the marginal or lower rainfall areas epidemic disease problems have not been as serious as in Europe and other countries. In the process of achieving higher yields in this area it will be necessary to take into account those diseases which will present a serious danger to production.

The problems of breeding for resistance in barley will be a repetition of the history of wheat breeding. Once resistance is incorporated into a barley variety it will not remain resistant foreever. These changes reflect the dynamic and ability of the microorganism to evolve. As a result the resistant varieties become susceptible and the frustrations of continually requiring to incorporate additional disease resistance will be necessary.

We have not carried out any systematic or detailed survey on barley diseases in this region of the world. Consequently, we cannot always place an adequate frequency or probability value on to the importance of any given barley disease. Summarizing the

data from the barley survey questionnaires sent to workers throughout the region provides one judgement value regarding the importance of certain diseases (see Table 2). Collectively, the diseases caused by Helminthosporium were considered the most important over all. Powdery mildew was judged to be the second most important disease. The remainder of the diseases were of either area or country specific in importance.

The Helminthosporium species of pathogens needs serious analysis because we are dealing with three possible species. Other diseases considered of importance are powdery mildew and the rusts which attack barley. As in wheat, there are three rust species which attack barley, but in the case of barley the rusts seem to be a more localized problem than in the case of wheat. Stem rust is often a minor problem because of the early maturity of barley and its tendency to escape from serious damage. Yellow rust seems to be a serious problem in the area of the Indian sub-continent and at extreme higher elevations (1500-2000 m) of the more tropical zones. Currently, Colombia is experiencing a severe barley yellow rust epidemic which is spreading to other Andean countries. Leaf rust is noted as a severe problem in the Mediterranean type climate areas. Scald can also be a serious disease where it occurs.

There seem to be only limited concern about loose, semi-loose and covered smut of barley. In our travels and observations we feel that these diseases have been underestimated as a problem. Again, caution and analysis of survey data must be done carefully because three described species of Ustilago are concerned.

There are a number of viruses which are recognized yet in this part of the world, we are not aware of any wide spread epidemic of virus having occurred on barley. The most commonly recognized barley virus disease is barley yellow dwarf virus. The vector (Aphis spp.) are commonly present and they themselves present a problem on occasions.

A number of other diseases certainly occur but they have not been observed with enough frequency to be considered of major importance at this time. We wish to emphasise the concept of "at this time". Drawing from our experience in wheat we know that the resolving of one problem often allows the expression of another to be observed. For example, when leaf rust resistance was in-

corporated into wheat we were able to observe some of the leaf spots. This is a feature beyond the incorporation of a susceptible character or the loss of resistance factors due to inattention. Another example is our lack of appreciation and information concerning the soil-borne pathogens. Only extreme cases are re cognized.

The diseases that attack barley are often similar to those observed in wheat or rye. The major diseases in common are the stem and yellow rusts (Puccinia graminis and P. striiformis), and powdery mildew (Erysiphe graminis) among the obligate parasites. The difference in these pathogens are the recognized formae speciales or the specialization ability of the organism to attack barley but not wheat or rye. As in the wheat rusts numerous races of the pathogen can be further distinguished by differential responses on varieties of barley. Scald of barley and rye caused by Rhycosporium secalis is similar to the obligate parasities in having evolved a forma speciales for the two host species.

A number of less specific (facultative) pathogens are also found on the three crops and on some of the grasses. Some of the more frequently encountered are scab (caused by Fusarium), spot blotch (Helminthosporium sativum) and some of the root and crown rot causing pathogens.

The disease caused by barley yellow dwarf virus is also common to many plant species and again specialized strains for the host and the aphid vector are present. A similar specialization is also possible to demonstrate for some of the nematodes related diseases.

The importance and difficulties caused by physiologic specialization in the pathogen does not require a detailed explanation to this audience. We should only add that the experience gained from wheat should be able to assist in dealing with this most difficult problem. However, we are also certain that the same debates and arguments as to which methods will provide the best and lasting results will be necessary. They will undoubtly be a repeat of the current and never ending discussion concerning this subject.

Barley, even with its similarities to wheat has many unique and special properties. Some have been mentioned previously by other speakers at the conference. In the area of barley diseases there are a number of specific disease problems that are not found

on the other cereal crops. The main one being the leaf rust of barley which is caused by Puccinia hordei. This is a distinctive rust with a different alternative host than the other rusts attacking barley and wheat. Other diseases that are specific to barley are the three smut diseases (Ustilago nuda, U. nigra and U. hordei) and net blotch and stripe caused by H. teres (Pyrenophora teres) and H. gramineum) respectively.

The magnitude of losses caused by the diseases of barley has not been well documented. This reflects partially the lack of attention and the fact that generally barley is grown in areas which minimize disease loss. In North America the general level of estimated losses caused by pests in general have increased over the years. This reflects an increased awareness, and better measurements along with increases in losses associated with higher average yield for a crop. The most valid estimates on losses for diseases and other pests are at best conservative. Some estimate losses due to diseases derived through calculations are presented in Table 3. Diseases cause the smallest loss in Europe which also represents the area where barley is the most important. In general, a larger commitment to breeding is present in Europe, and more chemical plant protection procedures are utilized. Weedicides seed dressings and foliar fungicides application are common agricultural practices.

In this region we are still in the process of identifying the diseases, trying to determine their importance and looking for sources of resistance. We have been impressed by the fact that we seldom find sources of resistance at multiple location testing sites. We seldom find multiple disease resistance. For example we have compared the average disease values of enough rusts of breadwheat, durum wheat and barley to draw some comparisons. On the average breadwheat has the best levels of resistance not only to one rust disease but to all three rusts (see Table 4). This is followed by durum wheat and finally by barley. We are speculating that this is not a difference in the potential variability for resistance in the species but reflects the amount of concentrated work on breeding for disease resistance. Compared to the effort on breadwheat or durum it is relatively small. If this interpretation is correct then the potential for increasing the levels of disease resistance and the possibilities for higher yield and adaptability in barley should be substantial. This also means our efforts in plant protection methods and evaluation must be substantially increased.

The other possible interpretation is to consider that little or no evolution of disease resistance factors has occurred because of the semi-arid areas where much of the barley has grown and evolved. This will have to be determined, and if true, will place additional burdens on the breeding and protection components of variety improvement. Under either circumstance we can only see a much greater effort being required from the plant pathologist and entomologists. The challenge in either case should prove to be stimulating and rewarding.

TABLE 1. Comparison of the ratio of grain production of barley and wheat to reported moisture in Regional Trials 1975-76. (From E.E.Saari and J.P.Srivastava, 1977)

Rainfall or Irrigation Reported in mm of Water (rounded to nearest 100)	Kilograms Grain Per mm of Water*	
	Barley	Wheat
200	7.5	1.1
300	8.0	6.1
400	8.7	5.6
500	3.4	8.7
600	5.6	7.8
700	4.7	1.6

* Derived by using the average mean yield for all entries in the nursery and dividing the reported moisture available during the growing season (12 RfWYT and 21 RBYT locations reporting).
(12 Rainfed Wheat Yield Trials and 21 Regional Barley Yield Trials).

TABLE 2. Summary of the ranking of the barley diseases considered most important by research workers.*

Region and Country	Disease and ranking* of importance							
	Stem rust	Yellow rust	Leaf rust	Powdery mildew	Helmintho-sporium spp.	Scald	Smut diseases	Virus
Near and Middle East								
Afghanistan	4	1	6	1	3	2	4	
Cyprus			1	3	2		4	
Iran	6	2	5	3	1	7	4	
Iraq					1		2	
Jordan	6	7	3	2	4		1	
Lebanon			2	1	4		3	
Saudi Arabia								
Syria				1				
Turkey	5	7	6	1	2	3	4	
Yemen, A.R.								
Yemen, P.D.R.	2	1						
North Africa								
Algeria		3	2	5	1	5	4	
Egypt	4		2	3	1			
Libya				2		3	1	
Morocco			3	5	1		2	4
Tunisia	7	6	4	3	1	5	2	

TABLE 2. Continued

Region and Country	Disease and ranking* of importance							
	Stem rust	Yellow rust	Leaf rust	Powdery mildew	Helmintho-sporium spp.	Scald	Smut	Virus diseases
East Africa								
Ethiopia	8	5	3	7	2	1	4	6
Kenya	4	3	5		2	1	6	
Suden		3	3					
Tanzania	6	5	3	4	1	2		
Mediterranean Europe								
Greece			3	2	1			
Portugal				3	2	1	4	
Spain	4	4	4	2	1		3	
South and Far East								
Bangladesh	2		3		1		4	
India	6	1	5	3	2		4	
Korea	5	5	5	4	2	6	3	1
Nepal	4	1	5	1	2	6	3	
Pakistan	3	1	2	2	4	5	4	

* Data from barley questionair : 1 = most important disease, 2 = second most important, etc.

TABLE 3. The estimated losses caused by different pests in barley (adapted from H.H.Cramer, 1967).

Region	Losses in % due to:			
	Insects	Weeds	Diseases	Total
North America	4.1	9.9	13.5	27.5
West Europe	2.0	7.0	4.0	13.0
North Africa	5.0	10.0	11.5	27.0
West Asia	5.5	10.0	11.5	27.0
World	3.9	8.8	8.3	20.9

Table 4. Frequency lines falling into different groups based on the Average Coefficient of Infection(ACI): Resistant ACI 0 - 5, moderately resistant ACI 6 - 10, moderately suspceptible ACI 11 -20 and susceptible 20 +. Data from Regional Disease and Insect Screening Nursery 1976-77

A.C.I. to the rust diseases	DISEASE & PERCENT OF ENTRIES IN EACH A.C.I. GROUPING								
	LEAF RUST			STEM RUST			YELLOW RUST		
	BW	DUR	BAR	BW	DUR	BAR	BW	DUR	BAR
0 - 5	35.3	4.5	1.4	40.8	33.8	54.8	55.1	63.0	8.5
5 - 10	15.2	8.3	0.5	18.5	15.7	22.1	17.1	13.5	5.4
11 - 20	21.7	39	2.2	23.3	29.7	18.1	15.7	14.8	14.5
20 +	27.8	48.2	95.8	17.4	20.8	5.0	12.1	8.7	71.6

BW = Bread Wheat DUR = Durum Wheat BAR = Barley

REFERENCES

Anonymous, 1960. Index of Plant Diseases in the United States. Agriculture Handbook, No. 165, pp.531.

Anonymous, 1953. Plant Diseases: The Yearbook of Agriculture , United States Government Printing Office, U.S. Department of Agriculture. Washington, D.C., pp.940.

Boewe, G.H. 1960. Diseases of Wheat, Oats, Barley and Rye, Illinois Natural History Survey Circular 48, p.157.

Bruehl, G.W., 1961. Barley Yellow Dwarf, Monograph Number 1, The American Phytopath.Society, p.52.

Cramer, H.H. 1967. Plant Protection and World Crop Production. Pflanzenschutz-Nachrichhten Bayer 20/1967. I Leverkusen, p.524.

Dickson, J.G. 1956. Diseases of Field Crops, McGraw-Hill Book Company Inc., New York, p.517.

Gaul, H. (Ed) 1976. Barley Genetics III. Proceedings of the Third International Barley Genetics Symposium 1976. Ab teilung fur Pflanzengenetik der Gesellschat fur Strahlen- und Umeltfoschung MGH, Munchen, p.849.

Last, F.T. 1971. The Role of the Host in the Epidemiology of Some Nonfoliar Pathogens. Ann Review Phytopath. 9:341-362.

Saari, E.E. and J.P.Srivastava, 1977. Improvement and Stabilization of Production of the Winter Cereals: Potentials in a Single Crop System. Mimeographed Paper. The Middle East and Africa Agriculture Seminar, Tunis, Tunisia, February 1-3, 1977. The Ford Foundation, New York. p.17.

IDENTIFICATION AND DOCUMENTATION OF DISEASE RESISTANT BARLEY GERMPLASM

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Introduction

Diseases cause reductions in production wherever barley is grown. Barley is not grown in many areas of the United States because of the severity of diseases. The most effective method for reducing losses in production from barley diseases is the development and growing of disease resistant varieties. Many different sources of resistance, each effective against the strains of the pathogens (disease causing organisms) in the area, are required for developing disease resistant varieties. The use of varieties with many sources of disease resistance will greatly reduce the chances of losses from new pathogenic strains of the pathogens and will increase the stability of the resistant varieties. The characteristics of both the host and the pathogen are important in determining the resistance of a host to a pathogen, since the reaction of the host to the pathogen is the result of the interaction between the host and the pathogen. I will describe the selection of hosts and pathogens, the determination and classification of host reactions, and procedures for the identification and documentation of disease resistant barley germplasm.

Selection of Hosts

New sources of disease resistant barley germplasm may be obtained by utilizing genetically diverse germplasm. If possible, all accessions in germplasm collections should be tested for their reactions to special cultures of the pathogens. If only a portion of the accessions in collections can be tested, then accessions should be selected which would be expected to have different sources of disease resistance. New sources of disease resistant barley germplasm may be obtained from the following:

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1. Areas of Co-Evolution of Hosts and Pathogens - Unique sources of host resistance to specific pathogens have been obtained in areas where the hosts and pathogens have coexisted for several thousand years (10). The plants which reproduce most prolifically when growing in natural populations in association with pathogens are those plants resistant or tolerant to the pathogens. When new pathogenic strains of pathogens occur, those plants which are resistant to the new pathogenic strains will become predominant in that natural population. When new pathogenic strains occur, plants resistant or tolerant to those new pathogenic strains must also occur. Several cycles of new pathogenic strains and new resistant or tolerant plants to those strains will have occurred after hosts and pathogens have coexisted for several thousand years. The more pathogenic strains to which a plant has developed resistance or tolerance, the more likely that plant will be resistant to new pathogenic strains. *Hordeum spontaneum* C. Koch has co-existed with the pathogens *Erysiphe graminis* DC f. sp. *hordei* Em. Marchal and *Puccinia hordei* Otth. in areas of Israel for over 5,000 years. Moseman and Craddock (11) tested accessions of *H. spontaneum* introduced from Israel for their reactions to composites of cultures of *E. graminis hordei* and *P. hordei*. They found that 75 percent of the accessions had plants resistant to *E. graminis hordei*, 55 percent resistant to *Puccinia hordei*, and 40 percent resistant to both pathogens.

2. Variable ecological conditions - Information on pathogenic strains of pathogens is not available in all areas where barley germplasm is found. When such information is not available, information on ecological conditions such as temperature, rainfall, and soil conditions may be helpful. Brown, et al. (1) identified a sorghum selection tolerant to high pH levels by identifying a location where sorghum was grown in high pH soils. Qualset (16) determined the relationships of disease resistant barley accessions introduced from Ethiopia in the USDA Barley Germplasm Collection. He found a high correlation between accessions resistant to Barley Yellow Dwarf Virus (BYDV) and elevation at which those accessions were collected and between resistance to BYDV and resistance to *Rhynchosporium secalis* (Oud.) J.J. Davis and *Ustilago nuda* (Jens.) Rostr. The pathogen *R. secalis* is known to grow best at the low temperatures which would occur at a higher elevations where the plants resistant to BYDV were most frequently found.

3. Centers of diversity - Disease resistant germplasm may be obtained in centers of diversity of the crop. Harlan (6) indicated that centers of diversity are characterized by very ancient agriculture and great ecological and human diversity. Regions of centers of diversity

in Africa, Asia, and southern Europe where there is barley germplasm are rapidly disappearing because of industrialization and the development of improved varieties.

4. Mutagenic agents - New sources of disease resistant barley have been obtained through the use of mutagenic agents. However, large populations must be tested and the plants may have other undesirable characteristics. Jorgensen (7) studied 11 mutagen induced genes for resistance to *E. graminis hordei* in barley. Those resistance genes were all recessive and at or near the Ml-o locus on chromosome 4 and caused decreased production in the absence of the pathogen.

Selection of Pathogens

The characteristics of the pathogens are as important as the characteristics of the hosts in identifying new sources of host resistance. Pathogens not only vary in pathogenicity, but new pathogenic strains often occur. The characteristics of new pathogenic strains of the pathogen are influenced by the sources of resistance in varieties growing in the area. Therefore, the pathogenicity of the present and future pathogens must be considered in selecting cultures for identifying sources of resistance. New pathogenic strains of the pathogen may be obtained from the following:

1. Areas of coevolution of hosts and pathogens - Unique sources of pathogenicity of pathogens to specific hosts have been obtained in areas where the hosts and the pathogens have coexisted for several thousand years (10). Several cycles of new pathogenic strains and new sources of resistance to those pathogenic strains have occurred in those areas. The more sources of host resistance to which a pathogenic strain has become pathogenic, the more likely that strain will be pathogenic on new sources of resistance.

Cultures of *E. graminis hordei* virulent on Psaknon, CI 6305 (10) and cultures of *P. hordei* virulent on Cebada Capa, CI 6193 (5), have been isolated in Israel where the pathogens and hosts have coexisted for over 5,000 years. Those two barley varieties had been resistant to all pathogenic strains of the pathogens from other countries with which they had been tested.

2. Collections from infected plants - Cultures of new pathogenic strains of pathogens are usually isolated from infected plants. The pathogen characteristics of those cultures are influenced by the characteristics of the infected plants from which they are isolated. The random occurrence of the pathogenic strains in nature can be obtained by isolating from varieties susceptible to most pathogenic strains of the pathogen. Some cultures with new pathogenic characteristics can be obtained by isolating from susceptible varieties, but new pathogenic cultures can be obtained more efficiently by isolating from varieties and selections with known resistance genes or which have been resistant in all previous tests when grown in special nurseries. Moseman and Greeley (12) isolated a new pathogenic strain of *P. hordei* from previously resistant lines in the uniform barley rust nursery. Eyal et al. (4) used mobile nurseries to isolate new pathogenic strains of *E. graminis hordei* from varieties with known genes or from selections previously resistant to all pathogenic strains with which they had been tested. Several new pathogenic strains of E. graminis hordei have been obtained by isolating cultures from previously resistant hosts (9, 14).

3. Testing cultures on special plants - Cultures with new pathogenic characteristics can be identified by testing on hosts with known resistance genes or which have been resistant in all previous tests. By testing new cultures of *U. nuda* on varieties and selections derived from Jet, CI 967, Moseman and Metcalf (15) isolated a culture which was virulent on some of those derivatives. They also showed how that culture differentiated between selections and varieties derived from Jet having only one resistance gene from those having both resistance genes.

Reactions of Hosts

Procedures have been developed for identifying the reactions of hosts to many different pathogens. The reactions are distinct, stable, and correlated with the production capacity of the plants. The reactions of plants have been determined in the seedling stage and in the field. The reactions of more plants can be determined by using seedlings. Seedling reactions are often more distinct and stable than field reactions because the environmental conditions, concentration of spores, type, purity, and proportion of pathogenic cultures, and growth and vigor of plants can be more accurately controlled. However, new sources of diseases resistant germplasm identified from seedling tests should be studied in the field to correlate the reactions of the plants to the production capacity of the plants.

The host reactions should be recorded on a standardized, computerizable scale. The scale 0 for immunity to 9 for susceptibility adopted by the International Rice Research Institute for recording reactions of rice plants to stresses should be satisfactory for recording reactions of barley to pathogens (3). Ratings of 3 or less represent resistance or acceptable reactions; ratings of 4, 5, or 6 represent moderate resistance or intermediate reactions, and ratings of 7, 8 or 9 represent susceptible or undesirable reactions. If only three reaction classes can be distinguished, they can be represented by 1 for resistant, 5 for moderately resistant, and 9 for susceptible.

Procedures for the Identification and Documentation of Disease Resistant Germplasm

Many sources of resistance to specific pathogens have been identified among the 16,000 accessions in the barley germplasm collection maintained in the Germplasm Resources Laboratory, Plant Genetics and Germplasm Institute, at Beltsville, Maryland. Many individuals have been furnished accessions from that collection for testing the accessions for their reactions to pathogenic strains of pathogens in their area. The reactions of at least 5,000 accessions have been determined to powdery mildew, barley stripe mosaic virus, cereal leaf beetle, hessian fly, and greenbug. Some data on reactions of accessions to pathogenic strains of those pests have been included in the information data bank on the collection.

The following are procedures for identifying and documenting disease resistant germplasm from preliminary tests and special nurseries and by developing sets of elite germplasm:

1. Preliminary tests - Accessions in barley germplasm collections and varieties or selections reported to be resistant to specific pathogens should be tested for their reactions in the seedling stage to a composite of virulent cultures. The inoculation procedure should assure the development of distinct, stable, and reproducible reactions. Controlling environmental conditions, concentration of spores, and growth and vigor of plants will aid in obtaining reproducible results. The composite of cultures should include all known virulence genes or characteristics of the pathogens. When cultures with new virulent characteristics are isolated, they should be added to the composite. By adding those cultures, sources of resistance to the new pathogenic strains can be identified before the new pathogenic strains become prevalent or cause severe epidemics. Many of the accessions resistant to such composites should be new sources of resistance and should be

useful in breeding new varieties resistant to those pathogens. Moseman (8) found that 229 accessions of the 6,273 accessions from the barley germplasm collection were resistant in the seedling stage to a composite of three cultures of the powdery mildew pathogen. Caddel (2) found that 2,608 accessions of the over 10,000 accessions tested from the barley germplasm collection were resistant to the powdery mildew strains present in Morocco. There are probably more resistant accessions in the barley germplasm collection, since many of the accessions in that collection have not been tested.

2. Special nurseries - The accessions resistant or moderately resistant in the preliminary seedling tests should be tested in special nurseries to determine their field or mature plant reactions. Those nurseries should be restricted to individuals having adequate facilities and staff and to areas where severe epidemics frequently occur. The number of special nurseries will be determined by the importance of the disease but they should not be for general distribution because of the detailed precise information desired. The reactions should be recorded on the standardized 0-9 scale, so that they may be summarized, computerized, and analyzed.

3. Elite germplasm - Sets of elite germplasm for reactions to specific pathogens should be assembled for distribution to individuals interested in studying the diseases caused by those pathogens or in developing new varieties resistant to those pathogens. The sets can be developed by analyzing the data obtained from the special nurseries and from special genetic studies. Accessions in each set should be resistant or moderately resistant to a specific pathogen. Additional information on each accession should be obtained from the data bank on the collection to aid in selecting those accessions with the most desirable characteristics for the special studies.

Procedures have been developed for determining the number and relationship of genes for resistance to specific pathogens of barley. The procedures require cultures with specific pathogenic characteristics and the ability to interpret genetic interactions within and between the hosts and pathogens. How cultures with specific pathogenic characteristics were used in determining the number and relationships of genes for resistance in barley to *U. nuda* and to *E. graminis hordei* has been described (13, 15). Procedures for determining other relationships between genes for resistance in barley to pathogens will not be described

since the procedures for each type of gene relationship depend on the characteristics of the hosts and pathogens involved in the disease and the genetic information available.

References

1. Brown, J.C., R.B.Clark, and W.E.Jones. Efficient and inefficient use of pH by sorghum. Soil Science Society of America Journal. (in press).

2. Caddel, John L. and Roy Wilcoxson. 1975. Sources of resistance to net blotch of barley in Morocco. Plant Dis.Reptr. 59:491-494.

3. Chang, T.T. 1976. Manual on genetic conservation of rice germ plasm for evaluation and utilization, 77p. International Rice Research Institute, Los Banos, Philippines.

4. Eyal, Z., Ruth Yurman, J.G.Moseman, and I. Wahl. 1973. Use of mobile nurseries in pathogenicity studies of Erysiphe graminis hordie on Hordeum spontaneum. Phytopathology 63: 1330-1334.

5. Golan, Tamar, Y. Anikster, J.G. Moseman, and I. Wahl. A new virulent strain of Puccinia hordei. Euphytica (in press).

6. Harlan, Jack R. 1975. Our vanishing genetic resources. SCIENCE 188: 618-621.

7. Jorgensen, J. Helms. 1976. Studies on recombination between alleles in the ml-o locus of barley and on pleiotropic effects of alleles. Induced Mutations for Disease Resistance in Crop Plants, p. 129-140, Technical Document, International Atomic Energy Agency, Vienna, Austria.

8. Moseman, J.G. 1955. Sources of resistance to powdery mildew of barley. Plant Dis.Reptr.39: 967-972.

9. Moseman, J.G. 1964. Inheritance of Pathogenicity in Erysiphe graminis f. sp. hordei in relation to breeding barley for resistance to powdery mildew. Crop Science 4:61-66.

10. Moseman, J.G. 1970. Co-evolution of host resistance and pathogen virulence, p. 450-456. In Barley Genetics II, 622p. Washington State Univ. Press, Pullman, Washington.

11. Moseman, J.G., and J.C.Craddock. 1975. Genetic basis for collecting, evaluating, and maintaining barley germplasm. In Barley Genetics III, 849 p., Verlag Karl Thiemig, Munchen, Germany.

12. Moseman, J.G. and L.W.Greeley. 1965. New pathogenic strains of Puccinia hordei among physiologic races identified in United States from 1959 through 1964. Plant Dis. Reptr.49: 575-578.

13. Moseman, J.G. and J.Helms Jorgensen. 1973. Differentiation of resistance genes at the Ml-a locus in six pairs of isogenic barley lines. Euphytica 22: 189-196.

14. Moseman, J.G., R.C.F.Macer, and L.W.Greeley. 1965. Genetic studies with cultures of Erysiphe graminis f. sp. hordei virulent on Hordeum spontaneum. Trans. Brit.Mycol.Soc. 48(3): 479-489.

15. Moseman, J.G. and D.R.Metcalf. 1969. Identification of resistance genes in barley by reactions to Ustilago nuda. Can.Jour.Pl. Sci. 49: 447-451.

16. Qualset, C.O. 1975. Sampling germplasm in a center of diversity: An example of disease resistance in Ethiopian barley, p. 81-96. In Crop Genetic Resources for Today and Tomorrow, 492p. Cambridge Univ.Press, London, England.

UTILIZING RECURRENT SELECTION POPULATIONS FOR DISEASE RESISTANCE IN BARLEY

E. L. Sharp and H. E. Bockelman*

Barley diseases are often the most limiting factor in barley production and may even persuade growers to shift to an alternate crop. Yet, in many of the semi-arid areas of the world, barley, due to its better adaptation to sub-optimum conditions and shorter growing period requirement, offers the greatest potential among cereal crops for total nutritive value. People living in the semi-arid regions should have the full benefits which can be derived by realization of the full potential in barley. Disease resistance often offers a most economical means of control and the recent exclusion of certain chemical treatments due to misuse and contamination of the environment places even more onus on breeding for disease resistance. Resistance, per se, is not difficult to obtain but difficulty is usually encountered in obtaining resistance which is broad based and of long duration.

We believe that barley has a number of attributes which should be exploited from the standpoint of reducing genetic vulnerability to plant diseases. Next to maize, the barley genome is probably the best understood in regard to numerous linkage associations and chromosome maps are becoming more and more complete. Genetic male sterility is known to occur at many loci and many other genes have been located which can be profitably used as genetic markers. With the use of trisomics, translocations, various genetic markers and, if necessary, mutagens it is possible to establish recurrent selection populations of stabilized homozygosity for a number of factors. At the same time other factors would fit a specific environment. Furthermore, the utilization of male sterility components greatly facilitates possibilities for recombination and pyramiding of genes for disease resistance. A number of methods or approaches have been advocated for decreasing genetic vulnerability and prolonging effective control of specific diseases. This paper discusses the

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the use of recurrent selection populations facilitated by genetic male sterility for developing disease resistance in Barley. The diseases which are currently being investigated are scald, net blotch, leaf rust, stem rust, covered smut, powdery mildew, barley stripe mosaic and yellow dwarf virus. Isolates of the pathogens being evaluated include both local isolates and isolates from the Middle East. Scald, net blotch, stem rust, leaf rust and barley stripe mosaic virus are receiving current emphasis.

In our work we are using three approaches in the development of recurrent selection populations (RSP's) with broad based disease resistance.

1. Development of agronomically good RSP's containing known major genes for resistance. These populations are established by crossing 10 to 20 adapted cultivars onto a male sterile source. One method is to then cross several cultivars with known resistance onto the RSP. This population is subsequently screened for resistance. RSP-5Rrs is a good example (see Fig. 1 for a description of its synthesis). This population was screened for resistance to scald under field conditions in 1976. Seed harvested from resistant plants has been released to a number of locations in the U.S. and Middle East to determine its reaction to local isolates of Rhynchosporium secalis. Seed of resistant plants returned from these nurseries will then be rebulked to begin another cycle of selection. Hopefully, this will result in a population with good agronomic types and resistance to a wide range of virulences of scald. RSP-5Rrs is a 6-row barley population but 2-row RSP's are also being developed.

   A second method is the use of a single gene transfer system. This method allows establishment of a population homozygous for a single major resistance gene, but heterozygous and variable for other agronomic characters without the necessity of screening for resistance in each cycle of selection. The procedure is as follows:

   (a) The chromosomal location of the resistance gene must be known. If necessary, trisomic analysis can be used to locate the gene. This was done for two scald resistant cultivars and three net blotch resistant cultivars. See Tables 2 through 6.

(b) A translocation stock with a breakpoint on the chromosome containing the resistance gene must be selected with its breakpoint distal to the resistance gene. This effectively prevents crossing-over of genes in the interstitial region. Selection of a translocation stock for scald genes on chromosome 3 is presently under way. Translocation stocks T1-3k, T3-4d, and T3-7d appear promising (see Table 7).

(c) The population can then be assembled using the resistant cultivar, the selected translocation stock, an RSP, and an optional marker gene in the same interstitial segment (e.g. seedling lethal).

The single gene transfer system will have the most utility for a major gene which has been stable over the years as pathogen populations have changed. A good example is the T. gene in barley for stem rust resistance. Attempts are currently underway to find a translocation breakpoint which will bracket this gene.

2. Development of broad-based RSP's containing many sources of resistance. The beginning populations for these RSP's are a bulk of the spring barleys in the world collection and CC XXX-F, a derivative of the world collection with male sterility. These populations are screened for resistance in seedling and field tests. To-date these two populations have been screened for resistance to stem rust, scald, and net blotch (see Table 8). The resistant plants are bulked to form a population containing many sources of resistance in a broad genetic base. The male sterility allows continuous recombination and accumulation of the resistance genes in the better agronomic types.

3. Development of RSP's with minor gene and/or generalized resistance. The base population is the world collection of spring barleys. Plants which show only low levels of resistance are retained. The progeny are then grown to determine if segregation is occurring. Lines which do not segregate, but continue to show these lower levels of resistance are bulked and crossed to a male sterile source. In this approach RSP selection continues for higher levels of resistance in an attempt to accumulate the minor genes. Attemps are also being made to identify plants exhibiting a slow rate of infection.

In a more tedious and time consuming approach (without the aid of male sterility) we have developed what appears to be non-specific resistance of wheat to stripe rust. It is believed that similar techniques can be utilized with diseases of barley. In clarification, a brief synopsis is given on the investigation of stripe rust of wheat.

Winter wheat cultivars appearing susceptible or intermediate in reaction to stripe rust were crossed. The susceptible cultivars were known to contain additive genes for stripe rust resistance even though they appeared susceptible under normal environments. This was determined by growing the plants at an extreme temperature and then comparing the reaction type with that obtained on Lemhi at the same conditions. Lemhi at 18/24° C (dark/light) still showed no signs of incompatibility but the other cultivars showed some evidence of chlorosis or necrosis. Crossings among these lines, after several generations of inoculation, selfing and selection showed a high type of resistance to the various virulence components occurring in the Northwestern United States. Some of these additive gene lines have been grown in international nurseries for 10 years and have still retained their uniform level of resistance. Furthermore, the lines have been challeneged with stripe rust isolates having virulence on all of the world wheat stripe rust differentials and have still exhibited a uniform high resistance. Table 1 illustrates a portion of the results. We believe the same type of resistance can be obtained for barley diseases using similar techniques. Male sterility in recurrent selection populations should greatly simplify the incorporation of additive genes for non-specific or, at least long lasting resistance.

Investigations on barley stripe, mosaic virus (BSMV) involve two aspects. First, since the disease is seed-borne, serodiagnosis of barley seed lots can be utilized to detect the virus in the seed and prevent its incorporation into barley stocks.

All stocks considered for release in the Middle East will be diagnosed and certified virus free. Additionally, resistance to seed transmission has been found in the variety Modjo and research is underway to locate this resistance in regard to chromosome or cytoplasm. Once identified the resistance can be incorporated into the RSP's as outlined earlier for other disease resistance. Rogueing of infected plants will also remove BSMV (except for latent types) from barley stocks.

Seedling tests for stem rust, leaf rust, scald, net blotch, stripe rust, Pseudomonas spot, and BSMV seed contamination were conducted on entries in the Elite Barley Yield Trial, which was released by CIMMYT, 1976 (see Table 9). Tables 10 and 11 also show seedling reactions of several barley varieties, including several resistant sources, to several isolates of scald and net blotch, respectively.

Fig. 1. Establishment of RSP-5Rrs, a m.s. recurrent selection population with resistance to scald.

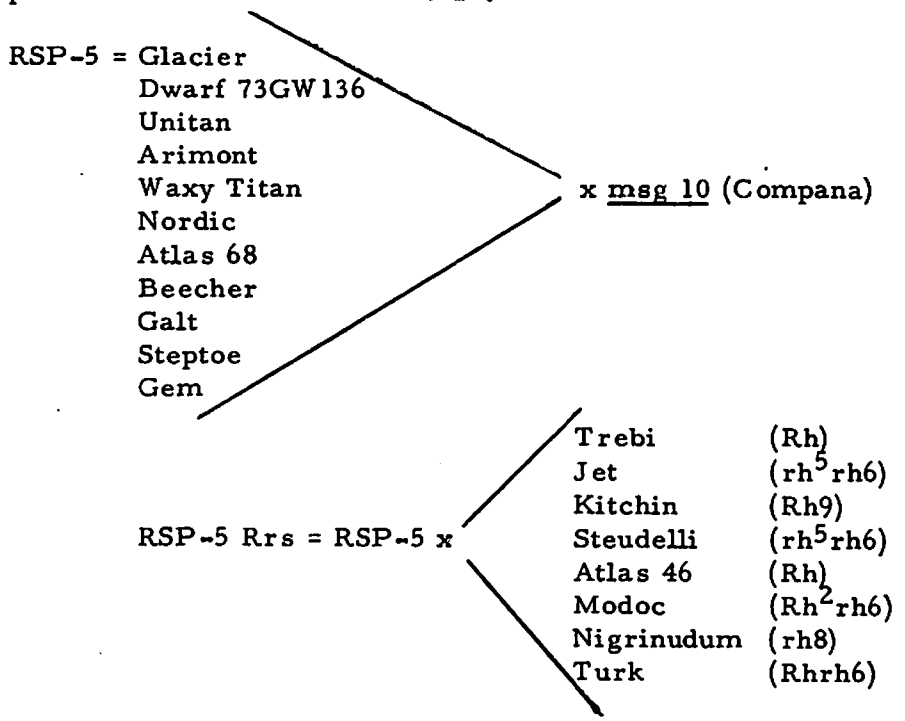

Table 1. Additive genes for general resistance to stripe rust.

Wheat Lines[b/] F_7	Reaction types of respective stripe rust isolates[a/]								
	Vil 23 USA	Moro USA	CI66 USA	Pn.CI66 USA	HK Eur	SO Eur	CI66 Eur	Clement Eur	Lee Eur
Sel A x Mt 6531	VR	VR	VR	VR	VR	VR	VR	VR	VR
Sel A x Lancer	VR	VR	VR	R	VR	VR	VR	VR	R
Sel A x Wanser	R	MR	R	MR	MR	R	R	R	--
Sel A x Mt 6930	R	MR	R	MR	MR	MR	R	R	R
Sel A x Delmar	VR	R	R	R	MR	MR	MR	MR	VR

a/ Reaction types: VR = very resistant, R = resistant, MR = moderately resistant.

b/ Sel A = additive gene line from Itana x P.I. 178383 containing one detectable recessive gene conditioning resistance to stripe rust.

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Sel A x Lancer	VR	VR	VR	R	VR	VR	VR	VR	R
Sel A x Wanser	R	MR	R	MR	MR	R	R	R	--
Sel A x Mt 6930	R	MR	R	MR	MR	MR	R	R	R
Sel A x Delmar	VR	R	R	R	MR	MR	MR	MR	VR

[a] Reaction types: VR = very resistant, R = resistant, MR = moderately resistant.

[b] Sel A = additive gene line from Itana x P.I. 178383 containing one detectable recessive gene conditioning resistance to stripe rust.

Table 2. Scald reaction class frequencies of F_2 seedlings of the Betzes primary trisomics x Kitchin

Trisomic	Reaction Class Frequencies 0,1	2	3	Total	x^2 3:1+
1	71	35	42	148	.901
2	98	30	33	161	1.741
3	174	58	83	315	.305
4	67	131	103	301	13.644**
5	150	51	82	283	2.385
6	184	40	81	305	.395
7	112	44	60	216	.889

+ (0,1,2):(3)
** significant at 1% confidence level

Table 3. Scald reaction class frequencies of F_2 seedlings of the Betzes primary trisomics x Jet.

Trisomic	Reaction Class Frequencies 0,1	2	3	Total	x^2 1:15+
1	12	92	75	179	.063
2	11	111	94	216	.494
3	4	153	139	396	12.685**
4	8	145	161	314	7.345**
5	28	167	125	315	.594
6	15	161	114	290	.575
7	24	168	138	330	.589

+ (0,1):(2,3)
** Significant at 1% confidence level

Table 4. Net blotch reaction class frequencies of F_2 seedlings of the Betzes primary trisomics X Tifang.

Trisomic	Reaction Class Frequencies 0,1	2,3	4	Total	X^2 3:1+
1	71	53	34	158	1.021
2	68	73	47	188	.0
3	99	120	111	330	13.127**
4	132	97	82	311	.309
5	120	93	68	281	.059
6	86	98	68	252	.529
7	81	70	57	208	.641

+ (0,1,2,3):(4)
** Significant at 1% confidence level

Table 5. Net blotch reaction class frequencies of F_2 seedlings of the Betzes primary trisomics X C.I. 7548.

Trisomic	Reaction Class Frequencies 0,1	2,3	4	Total	X^2 3:1+
1	61	46	30	137	.703
2	40	48	72	160	34.133**
3	145	87	78	310	.004
4	118	107	69	294	.368
5	112	97	77	286	.564
6	123	79	75	277	.636
7	70	68	50	188	.255

+ (0,1,2,3):(4)
** Significant at 1% confidence level

Table 6. Net blotch reaction class frequencies of F_2 seedlings of the Betzes primary trisomics X C.I. 9819.

Trisomic	Reaction Class Frequencies 0,1	2,3	4	Total	X^2 15:1+
1	101	90	15	206	.374
2	96	105	18	219	1.450
3	120	160	33	313	9.845**
4	173	116	12	301	2.631
5	116	148	26	290	3.650‡
6	159	108	21	288	.533
7	90	91	16	197	1.178

+ (0,1,2,3):(4)
‡ P = .05-.10
** Significant at 1% confidence level

Table 7. Scald reactions of F_2 lines of crosses between T3 translocations and scald resistant cultivars (fertile plants).

Cross	No. of F_3 lines homozygous resistant	segregating	homozygous susceptible	Total
TI-3c x Modoc	19	9	22	50
TI-3e x Atlas 46	12	3	18	33
TI-3f x Osiris	17	4	27	48
TI-3k x Atlas 46	23	1	26	50
T2-3e x Modoc	23	4	23	50
T2-3f x Atlas 46	20	4	25	49
T3-4d x Atlas 46	21	2	26	49
T3-6c x Modoc	16	5	29	50
T3-7d x Atlas 46	43	1	6	50

Table 8. Reaction of two broad-based populations to three diseases.

Population	Reaction	Stem Rust	Scald	Net Blotch
CC XXX-F	Resistant	4.5%	34.5	16.9
	Intermediate	5.2	7.6	30.5
	Susceptible	90.2	57.9	52.6
World Collection (spring)	Resistant	5.8	20.3	20.0
	Intermediate	4.2	14.3	39.3
	Susceptible	90.0	65.4	40.8

Table 9. Seedling reaction to several diseases of entries in the Elite Barley Yield Trial (EBYT, Early), 1976. Diseases evaluated*

Variety	Stem Rust	Leaf Rust	Scald	Net Blotch	Pseudo-monas
CM-67-11016.2	MS	R	S	R	S
11016.2-Weeah	S	MR	S	I	S
Por x Ds-Apro/CM67-Dwg2	S	S	S	MR	S
CM67-U.Sask. 1800 x Pro-CM67	S	MR	S	R	S
Porvenir	S	MR	S	MR	S
Apam-Godiva	MS	R	S	I	S
Mona-Arivat	S	MR	I	I	S
Apam-RL x Apam-Dwarf II-1Y	MR	R	S	I	S
Cadelilla "S"	I	R	S	I	S
11012.2	S	I	S	I	S
M66.95-M66.123 x BGS 0252	R	R	S	I	S
Hja C4715 x 011i - M64.69	MR	R	S	MS	S
Hja C4715 x 011i - M64.69	MR	MR	S	S	S
M66.83 - Larker L.S. x Apam-RL	MR	R	S	MR	S
Mona	S	R	S	S	MS
M66.83 - Larker L.S. x Apam-RL	MR	R	S	MR	S
Apam-RL x Kristina	MR	R	S	MR	S
Mari - Coho	R	R	S	S	S
M65.167-M66.69.1 x Mona	MR	R	S	MS	MS
S.Precoz (2h)	S	I	S	S	S
CR115-Por x S. Precoz (6h)	I	R	S	MS	S
ER-Apam	S	I	S	I	S
ER-Apam	S	MS	S	MR	S
M69.69 x Apam-RL	S	S	S	MS	S

R = resistant
MR = moderately resistant
I = intermediate
MS = moderately susceptible
S = susceptible
There is no BSMV seed contamination.
* stem rust -Race 15B
Other diseases - a mixture of isolates from Montana and the Middle East.

Table 10. Seedling reactions of barley cultivars to isolates of *Rhynchosporium secalis* (Scald)

Cultivar	Isolate			
	Creston, MT	Lewistown, MT	Lebanon	Turkey
Atlas 46	0*	0	0,1	0
La Mesita	0	0	0	0
Trebi	1,2	1	1,2	1
Osiris	0	0	0	0
Jet	1	1	1	1
Steudelli	1	1	1	1
Kitchin	0,1	0	0	0,1
Modoc	1	1	1	1
Brier	0	0	0	0,1
Betzes	2	3	3	2
Bonus	2,3	3	2,3	3
Hannchen	3	3	3	3

* 0 = (very resistant) no symptoms observed
1 = (resistant) small brownish lesions on tips or margins of leaves
2 = (intermediate) marginal lesions extended in length and/or well-developed "scald" lesions
3 = (susceptible) leaves collapse and wilt.

Table 11. Seedling reactions of barley cultivars to isolates of *Pyrenophora teres* (Net Blotch)

Cultivar	Isolate				
	Rudyard MT	Sidney MT	ES8 (Tunisi)	ES9 (Tunisia)	ES10 (Lebanon)
C.I. 5791	1*	1,2	1	1	1
Tifang	2	3,4,2	1	1	2
Oderbrucker	3,4	3,4	2	1	1
C.I. 7584	1	1,2	1	1	--
C.I. 2235	2,1	1,2	1	1	--
C.I. 9776	1	1	1	1	--
C.I. 9819	1	1	1	1	2
Terbi	4	4	4	3	3
Betzes	4	4	4	4	--

* 0 = (very resistant) no observable infection
1 = (resistant) pinpoint lesions without chlorosis
2 = (moderately resistant) slightly developed dark brown lesions with no chlorosis
3 = (moderately susceptible) restricted longitudinal brown streaks with slight chlorosis
4 = (susceptible) brown elongated lesions, criss-crossed with dark-colored net-like venation and marked chlorosis

SEED AND FEED QUALITY

SEED QUALITY AND PRODUCTION

A VITAL LINK TO NATIONAL BARLEY PRODUCTION PROGRAMS

Johnson E. Douglas*

A Vital Link

Strengthening national barley research programs is not enough. Parallel initiatives are needed to improve good quality seed supplies which are limited in many countries. This step becomes the vital link to successful national barley production programs. In other words, this formula applies: Improved barley varieties plus good quality seed (and other necessary inputs) equals satisfactory farmers' results.

How good is the "good quality seed" portion of that formula in each national program? What is needed to get more good quality barley seed available and used? Often an appraisal of what currently exists is required. (Douglas, 1969). Questions that need to be asked include:

1. Are new and improved barley varieties available?
2. How available are good quality seeds of barley?
3. How effective are the present seed multiplication, processing, and marketing efforts?
4. How effective are the seed quality control programs?
5. Are the educational and promotional efforts on barley seeds sufficient?
6. Is the role currently played by the government and non-government sectors well defined and correct for the situation?
7. How good are the communications among the different sectors of the total seed industry?
8. What kinds of priorities need to be placed on the steps to be taken to improve the program?

After leaders in national programs ask these questions, they are in a better position to make the necessary judgments on the steps needed for moving forward on an improved seed program for barley.

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Barley Seed Status

It was not possible to obtain a current evaluation of the status of barley seed production in the region prior to this meeting. An evaluation of the seed industry in the region, based upon results of a FAO seed review, was presented at the 3rd Regional Wheat Workshop in 1975. (FAO, 1973) At that time, a few points, which are relevant to our present discussion, stood out.

1. No specialized agencies were concerned with seed multiplication of Breeder and/or Basic Seed in the Middle East Region.

2. The seed production, processing, and storage was handled in three countries by cooperatives, in five countries through a blend of government farms and government agencies contracting with the farmers, and in seven countries with the production totally on government farms. Seed distribution was handled principally by the Ministry of Agriculture or an agency closely associated with it. In a few cases, cooperatives, wheat boards, and commission agents were playing a role.

3. Nine countries had standards for wheat and some inspection activities. Seven countries reported no standards. Three countries reported having a seed law, three were considering or preparing legislation, and nine had none.

4. Seven countries in the region were members of the International Seed Testing Association.

5. Eleven countries reported a wheat seed subsidy, one relied primarily on credit, one indicated a fixed price, and three did not answer.

6. The amount of wheat seed distributed officially, compared with the total needs of each country, ranged from less than 3% to something above 20%.

Progress has undoubtedly been made since that summary was prepared. However, my general observations are that the availability of barley seed is less satisfactory than for wheat seed. Several factors have affected this.

1. The barley varieties available are not superior enough to stimulate farmer demand for seed. The development of superior varieties is of prime importance to this group. Your research will result in better varieties in the future. However, until this occurs, it will be difficult to develop a meaningful seed program.

2. It is difficult to develop a reliable commercial seed market. This may be difficult to overcome. Since barley tends to be used in less productive areas where the risk of a crop failure is higher, farmers are less inclined to invest in seed unless they are convinced that their chances of success are good. In situations where barley may or may not be used depending upon weather conditions, it is also difficult to establish a reliable market because the demand for seed can fluctuate considerably from one season to the other.

3. Inadequate attention is given to barley seed supplies. In many countries wheat is a much more important crop, so more attention is naturally given to wheat seed supplies. Attention and facilities normally are directed toward meeting the barley seed needs only after the wheat seed requirements are reasonably satisfied.

Getting More Good Quality Barley Seed Produced and Used.

Assuming that improved varieties are available for multiplication and use, a few essentials are required to produce and use more good quality barley seed.

1. A means is needed to multiply the small quantity of seed of new varieties in the research program so it can be distributed to several individuals or agencies.

2. An effective production, processing, and marketing mechanism is required.

3. Methods must be available to assure that the seed distributed is of good quality.

The first two classes of seed multiplied from a plant breeder's original material and used in a seed certification program are often called Breeder Seed and Basic Seed. These two stages of multiplication cannot be left to chance. Either the crops research program must assume the responsibility for these stages of multiplication or arrangements must be made for a special agency or unit to do this work. Many programs suffer because plant breeders do not have the time for, nor do they enjoy, seed maintenance and seed multiplication work. Where the work is done within the crops research program, a "seed maintenance technologist" who would have primary responsibility for this step could be an excellent addition to many programs. This person should work closely with the plant breeder responsible for barley, but his primary responsibility would center on seed maintenance and multiplication.

After Basic Seed or seed of an equivalent multiplication is available, a decision is needed on the use of this seed. In the short run, and under certain situations, it may be better to distribute this seed in "mini-kits" to supply a large number of farmers with seed for trial and their own multiplications. Where no alternative seed multiplication mechanism exists or where seed marketing is difficult, such an approach may be the best solution. This method is only a short-term solution to an immediate need.

On a long-term basis, mechanisms are needed to multiply and market Certified Seed and/or commercial seed. These multiplications require the availability of Basic Seed or its equivalent. Organizing this stage to meet required needs has not been easy in most countries. If satisfactory means do not exist to multiply and market seeds, the formation of seed enterprises to achieve this objective appear to be the most workable solution in most countries. (Douglas, 1973).

In building such a seed production, processing, and marketing capability, various alternatives exist. In a publication on seeds being developed by the International Agricultural Development Service, five categories of seed enterprises are considered.

1. Private Sector -- seed enterprises which have their own research programs and totally control their seed multiplication and marketing functions.

2. Private Sector with Government Assistance -- seed enterprises which receive various kinds of assistance from government, such as publicly bred varieties, Basic Seeds for further multiplication, special credit concessions, subsidies, and non-interference in pricing.

3. Private Sector plus Maximum Government Assistance -- seed enterprises and seed production activities which utilize the assistance of number 2 and also benefit from equipment and facility leasing and hire-purchase arrangements, special uses of government staff, marketing help, and other measures that stimulate "seed multipliers".

4. Private Sector with Direct Government Participation -- joint seed enterprises involving both private and public capital with assistance as outlined in numbers 2 and 3.

5. Only Government Participation -- seed enterprises and seed production activities with only government participation in one or more aspects of the seed growing, processing, distribution, and marketing programs.

Barley seed production, processing, and marketing can be organized in any one of these ways. Many countries use a combination of these approaches to meet their seed supply needs. Such seed enterprises normally deal with several different crops. In most countries the logical step is to identify the existing channels of seed movement, to strengthen these efforts, and to add barley to them.

One objective in utilizing seed enterprises would be to let them carry the major responsibility for marketing the seeds they are producing. However, in the case of barley, which is to be distributed in marginal production areas, special distribution and marketing efforts may be needed in order to initiate a program. This might involve using various public sector agencies, which already have contacts in the area, as retail distributors for the seed enterprises. It could include using leading farmers and selected villagers as retail distributors of seeds. Seed enterprises might utilize seed sale vans to visit country bazaars on a regular basis. New ways of getting seed to farmers need to be explored and tested.

Assuring good quality seed to the consumer is a concern of both the seed enterprises and the government. The seed enterprises should develop their own quality control program to establish a reputation for supplying only seeds of high quality. If the government is the producer and distributor of seed, quality standards should be established by the concerned governmental unit with steps taken to assure that only seeds above those standards are distributed.

An addition, common, governmental responsibility is to provide for a seed certification program. Under this program the field inspection, testing, and labeling of certified seed should be offered to seed enterprises and seed multipliers in a way that the program can be accepted by them voluntarily. Seed legislation can be drafted that officially recognizes a seed certification scheme. Seed legislation may also be developed and enforced to assure that all seed marketed has been truthfully labeled and/or achieved certain quality levels. These provisions are often mandatory and apply to both certified seed and all other seed. If barley is not already included under existing seed legislation, it could be added with specific provisions for minimum germination and purity levels and a need for labeling seed before it is sold. Additional details on seed certification and seed legislation for cereals can be found in Cereal Seed Technology, 1975.

The Barley Researcher's Role

It is easy for a plant breeder, plant pathologist, or an agronomist to say, "These points are all very good, but they do not apply to me. My concern is only developing the variety." Is this really true? It is in the researcher's own interest to work for a strong seed production and marketing program for his role is vital to its success.

The responsibility for supplies of Breeder Seed, and often Basic Seed, fall on the shoulders of the crops researcher. He may find ways to shift some of this work to a special unit or to an organization for meeting this need as indicated earlier. However, the final responsibility still rests on the crops research program.

If the barley varieties are better, the crops researcy program must clearly demonstrate this to seed multipliers and information people. The crops researcher needs to interpret research results and put them into a clear, concise form for seed multipliers and information people.

Good descriptions of varieties are needed for seed certification purposes and for seed multipliers. The primary responsibility for these descriptions rests with the plant breeder.

The descriptions must then become meaningful through training to seed certification personnel and those involved in maintaining and multiplying the variety. Again the crops research program has a major responsibility to assure that this job is done well.

Many seed enterprises have been formed by crops research people who saw a need and worked to meet that need. Many seed enterprises are managed by former crops research personnel. After all, they are often the most capable and well trained people available. To initiate and build a seed enterprise is a challenge as interesting as developing new varieties.

Developing effective seed programs is difficult. Thus, the crops researcher's role, when properly related to the work of others, is vital in achieving this objective. National barley production programs succeed only when an effective means is developed to provide good quality seed of the best varieties to farmers.

Literature Cited

Douglas, J.E., 1969. "Seed Improvement in Developing Countries -- Building a Comprehensive Program", Proceedings International Seed Testing Association, Vol.34, No. 3, p.429.

Douglas, J.E., 1973. "Essential Components of Seed Industries, Examples of Successful Implemented Activities -- Seed Production". The Role of Seed Science and Technology in Agricultural Development, FAO, Rome, pp. 97 - 107.

Food and Agriculture Organization, 1973. FAO Seed Review 1971-72, AGPC: Misc/20, Rome, pp. 1, 2, 9, 10, 17, 22, 25, 29, 34, 36, 38, 42, 45, 47, 49, 51.

Food and Agriculture Organization, 1975. Cereal Seed Technology, Rome, pp. 163-211.

THE POTENTIAL OF UTILIZING GENES FOR IMPROVED QUALITY IN BARLEY FOR FOOD AND FEED

By

Lars Munk

Introduction

In recent time barley has declined in importance in comparison with breadwheat. Beermaking was introduced much earlier than the baking of fermented bread from breadwheat (Triticum vulgare); a development made by the plantbreeders at that time (about 3000 years B.C.) which has never been outmatched by modern refinements in food science. Wheat, due to its palatability when prepared as bread, has from early times received considerable technological attention - especially by the milling machine industry - while barley, in the few places where it is still used as food is, still prepared and cooked by methods similar to those in use during the bronze age. Barley, at least from the nutritional point of view, has the same potential nutritive value as wheat and has the advantage of having a much broader range of adaptation under both hot dry and subartic conditions. It is also relatively resistant to high salinity in the soil. In order to utilize the advantages of barley as a crop and as a food in the future, it is obviously necessary to improve its food processing and acceptability characteristics. Without improving such factors as the milling and dehulling procedures, promising high lysine lines would only show their importance in the feed sector and will never make any direct impact on human nutrition.

What is required is a development in barley similar to that which our colleagues made in wheat 6000 years ago. This does not necessarily mean that we would try to copy them and develop a barley with a gluten-like protein for baking - we obviously have to be more imaginative and do something which is both simple and original and which would attract the taste of the people.

First, we should record how barley is currently used in the home throughout the world, so that we are able to increase our understanding of the factors of importance for food processing which might

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be genetically manipulated. We will then surely find that the genetic resources we already have in barley and which in many respects are unique to this cereal, will give us a firm basis for this work.

Barley for food (see Table 1)

The rough design of the barley seed, the rough husk with the thick pericarp and testa and the triple aleuron layers introduces serious problems with regard to the full utilization of barley as a food. The fiber-rich pericarp is not edible and contains tannins and anthocyanogens which impair digestion and influence taste. The testa also seems to have little food value as such, except for the B-vitamins and the dietary value of the fiber as a bulk. Substances from the outer layers of barley affecting taste and acceptability should be identified.

The naked barley varieties simplify hand milling but introduce new problems when seed production is mechanized because the germ is easily damaged during threshing,resulting in a low germination capacity. Thus it appears necessary to breed for a more retracted or protected embryo in the naked barley if such varieties are to be a success. Naked barley still has to be milled to remove the testa and the aleuron layer to meet the standards required for barley food products available today.

It is possible with milling technology to abrade barley and almost completely remove the pericarp and testa. At the Carlsberg Research Mill we are now experimenting with this technology to produce starch-rich products for brewing. This milling technique in combination with an integrated plantbreeding program may also produce new barley products suitable for food preparation. In table 2 a milling experiment with the covered barley variety Bomi is shown. By a few cycles of dehulling it is possible to completely remove the pericarp and the testa (except in the crease) and thus without crushing the seed reduce fiber content from 4.90 to 0.65 percent and ash content from 2.08 to 1.23 percent on a dry matter basis. For an efficient abrasion process, the hardness of the seed is of a paramount importance. With sufficiently hard seeds it is possible to completely remove the aleuron layer (except in the crease) with a very little breakage of kernels. The high-lysine gene (lys) from Hiproly is especially valuable here because it is associated with hard seed with improved abrasion milling characteristics and also avoids losses of endosperm in the bran meal during the process.

In barley cooking, the gelatinization, temperature and viscosity of starch is of great importance in obtaining the desired consistency of the foods. The amylopectine/amylose ration determines the uptake of water and consistency after cooking. As high content of amylopectine gives rise to soft and glutinous products with a high water content while a high amylose content results in a dryer and harder product. The breeding problems here are comparable with those of rice and it should thus be possible to draw on the experience of the rice breeders. In barley the "waxy" gene (100 percent amylopectine) would give very glutinous products suitable for soups while the "Glacier" high amylose gene would give the opposite effect.

Abraded 1508 barley which has a very favourable amino acid composition for human growth would after steaming, milling and supplementation with vitamins and minerals produce an instant baby food where all the protein and the carbohydrates come from barley. The nutritive value and the storage quality of this product should be equal or superior to commercially produced baby foods currently on the market and the production cost should be considerably lower, even if one has to pay a premium to growers because the high lysine lines still have 10-20 percent reduced yields compared to standard varieties.

Barley for brewing - malt and adjunct (see Table 1)

One of the major aims of the brewer is to produce a cheap source of sugar (glucose) to nourish the yeast in the fermentation process. The production of glucose is brought about by the germination (malting) process by which barley is transformed into malt and during which enzymes are produced, then enzymes break the starch into glucose in the mashing process in the brewhouse. It is obvious that factors contributing to a high starch content of the seed such as a large seed size and low protein content would increase the amount of sugar (extract) which can be produced in the mashing process and which can be fully utilized in the fermentation process. There are several other factors of decisive importance in brewing technology and in the stability and taste of the finished beer.

During the filtration of the mash in the brewhouse the husk is used as a filteraid (this is why brewers are not interested in malt from naked barley) in the mash filter. Certain gum substance like beta-glucanes gives high viscosity and slow down the filtration process appreciably. The betaglucanes are partly broken down during the malting and mashing process by beta-glucanase. This process is

the limiting factor in the malting process today and makes the maltster prolong the costly malting process beyond that which is needed to produce enzymes (alpha and beta amylases) for breaking down the starch. Low beta-glucane varieties should therefore be an important aim for the plant breeder.

Preliminary screening trials in our laboratory show a great genetic variability in the viscosity of acid barley extracts, demonstrating the possibility of finding low beta-glucane varieties which could be used in the breeding program. The content of anthocyanogens in the outer layers of the barley seed both contributes to the taste of the beer and interferes with the quality of the beer because they give rise to precipitate with proteins and effect beer clarity after prolonged storage. An anthocyanoges free barley mutant has been identified in the Carlsberg Laboratory. It will be possible in the future to control the level of anthocyanogens in malting barley by plant breeding.

In the malting process an excess of alpha and beta-amylases for the breakdown of starch are produced. This excess could be used for the digestion of unmalted starchy adjuncts from e.g. maize, wheat and barley which could be added in the brew-house. It is possible, by applying different milling technologies, to produce an enriched starchy fraction for the breweries and a feed fraction rich in fiber, fat and protein. If barley is used as adjuncts there will be an even greater need for the development of low beta-glucane varieties in order not to run into filtering problems.

Barley for feed

Nutritionally we seem to know a lot more about feeding animals than the feeding of man. There are very few nutritional studies on barley as human food in spite of the fact that barley has been a major food for millions of people for thousands of years. I personally know only one report (Hindhede 1914). On the other hand the information from feeding trials with animals is overwhelming. In many countries such as Denmark, proteins, rich in lysine and other essential amino acids are imported as a feed for monogastric animals and ruminants. If we could improve the amino acid composition of the barley protein, which makes up 50-75 percent of the protein in current mixed feed diets, we could save about 50% of the imported protein for monogastric animals. I have earlier (Munk 1976) made an attempt to describe the logistics behind the breeding of the so-called high-lysine barley types

for food and feed and I will here merely dwell on the plant breeding aspects of the development of high lysine barley.

The dye binding (DBC) or Udy method - combined with the Kjeldal protein analysis was first used as a screening method for lysine content in barley breeding, at the Swedish Seed Association at Svalof, and the first high lysine barley - the Ethiopian Hiproly barley - was selected from the world barley collection in 1967. Later (1972) the Danish Atomic Energy Commission Institute at Ris, Denmark, isolated the 1508 mutant using the same DBC method from mutagen treated material. The 1508 mutant displays an amino acid profile ideal for feeding pigs. It also has an ideal amino acid composition for use as a baby food for human consumption. In Svalof about 5000 lines from the World collection have now (1977) been screened and only one positive line (Hiproly about 25%) has been found, whereas at Ris about 30,000 M plants have been analysed and 15 mutants have been isolated. Two of these mutants have a low lysine content and three are of the radical 1508 type, all three being allelic. The other 10 mutants have a lysine improvement (lysine g/100g protein) which is less than that of Hiproly (below 20 percent in comparison to normal barley). The limiting factor in breeding for improvement in the amino acid composition of barley is not protein quality - those types we already have - but the yield of these types which lags up to 20 percent behind the commercial barley varieties.

In Hiproly, the shriveled grain of the original Ethiopian variety is easily overcome, at least in temperate humid regions. It should, however, be investigated in an exchange program to see whether plump Hiproly, high lysine segregants from these regions are as plump as normal material when grown under more arid and hot climatic conditions. The main problem in breeding the Hiproly gene is that frequently the lysine value falls when yield is improved which means that the lysine level must be carefully checked by the DBC analysis in each selection cycle. This is not a problem in breeding with the 1508 gene in barley but it seems difficult to solve the problem of shrivelled grain. The Carlsberg Research Center have tried in four ways to overcome this problem in the 1508 gene.

1. It has crossed the 1508 mutant (and backcrossed the F1's) with large seeded commercial varieties. After analysing plants with plump seeds from the proceeding generations with the DBC method we have so far, in spite of extensive work, been unable to isolate a single plump, high lysine segregant.

2. It has crossed 40 different lines from the World barley collection with each other in different combinations to obtain a variable genepool.

   The F1 plants from these crosses have then been crossed with the 1508 barley and about 12,000 plump seeds from the proceeding generations - have been analysed by the hordein precipitation screening test as developed at Plant Breeding Institute in Cambridge. So far, we have not been abl e to obtain one single non-shrivelled 1508 type.

3. It has treated the 1508 barley with azide to see if we could induce a positive plump mutant still retaining the high.lysine condition. After Screening 150,000 M1 spikes we have not reached this goal.

4. Finally we have tried to induce new mutants in the naked barley variety Nakta. Because the 1508 mutant is opaque as seen in the lightbox (as with opaque -2 in maize and sorghum), we tried to identify opaque plump seeds in a M1 generation from azide treated Nakta. There is a very high mutation rate with regard to the opaque character (up to 20 percent) most of which are shrivelled. About 200 plump opaque have been analysed out of 100,000 seeds from 2500 plants. The seeds were planted 14 days ago but unfortunately the germination is down to about 10 percent. This decline is due to damage of the embryo during threshing, and presumably partly due to the induction of lethal genes from the azide treatment.

The current experience seems rather negative. Nethertheless, I am confident that somebody will sooner or later obtain a plump 1508 type of barley. Dr.Axtell at Purdue University, Lafayett, U.S.A., has been able to obtain both shrivelled and plump opaque, high lysine seeds from sorghum an undertaking which demonstrates that it may be possible in other crops, it is also an interesting fact that the three 1508 shrivelled mutants which were obtained at Ris are all allelic. This points to a limited number of loci for this drastic type of mutant which apparently is of a very fundamental biochemical and genetical nature. In fact we now seem to enter the area of gene regulation in eucaryotes an almost completely unesephoner area of biological science.

Literature

Hindhede, M. 1914 Fuldkommen Sundhed og vejen dertil P.106 Copenhagen, Munch, L.1976. Aspects of the selection, design and use of high lysine cereals. P.3-17 Proc. from the IAEA Symposium: Evaluation of seed protein alternations by mutation breeding. IAEA Vienne.

Munk, L. 1975. Developing the concept of quality in Barley breeding programmes for malt and feed. Barley genetics III Proc. from the 1975. p.526-535.

Table 1.

Plant Breeding - Quality

Barley for Food - Dehulling and Debranning:

Seed type (naked, covered)
Uniformity of seeds
Roundness - Globosum Mutants
Hardness
Cooking Characteristics (Anylose - Amylopectin ration)
Amino Acid Composition

Barley for Malt and Adjunct:

Seed uniformity and shape (filtering characteristics)
B - Glucanes (Filtering Characteristics)
Anthocyanogens (beer stability)
Enzyme Development During Malting
Extract Content
Protein Content

Barley for Feed:

High Content of Protein and
Amino Acid Composition and Energy.

Table 2

Debranning of Barley (Bomi)

Analysis are on Dry Matter Base.

	Product		Bran	
	Fiber	Ash	Fiber	Ash
Raw Material	4,90	2,08	28,50	3,82
1st Dehulling	0,65	1,55	9,60	4,89
2nd Dehulling	0,65	1,32	7,4	3,57
3rd Dehulling	0,65	1,23		

IMPLICATIONS OF BARLEY BREEDING FOR FOOD AND FEED QUALITY

By

C.W. Newman*

Introduction

Slightly more than a decade has passed since Mertz et al. (1964) reported their findings with Opaque - 2 corn. In the ensuing thirteen years, many scientists of widely different backgrounds and nationalities have endeavored to improve world nutrition through the location and development of cereals with superior protein content and quality. Much has been accomplished in improved yield and genotypes of maize which have the Opaque - 2 gene. High-lysine gene sources have also been discovered or developed in grain sorghum and barley as well as in maize.

The major deterent to wide acceptability of the high-protein, high-lysine cereals has been a 10 to 20% decrease in yields. According to Pomeranz (1975) "yield is of utmost importance because: a) the amount of available protein depends largely on the quantity of grain which is produced and b) the nutritionally improved crop must reap an adequate economic return to the farmer". Frey (1973) and Whitehouse (1973) reported that a negative correlation exists in all cereals between grain yield and protein content of the grain. It would seem that protein quality may also be negatively correlated to yield in cereals. It is possible that cultural practices currently employed may be partially responsible for the rate limiting effect of protein content and quality of cereal grains on yield. The challenge to todays scientist is to develop cereals of tomorrow's people. Agro-engineering in soil and water use may ultimately be as important as breeding for yields, quality, disease and drought resistance in cereals.

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Now is not the time to abandon our efforts but rather to push forward in an exciting and critically important scientific field that is actually still in its infancy. We must remember the very short span of time it has taken to reach our present level of knowledge and we must endeavor to produce cereals crops which enjoy both yield and nutritive quality. Dietary calories are of unquestionable importance but calories without quality protein are of little value for optimum growth, reproduction and general good health We cannot plan to feed the world of tomorrow with the products of yesterday.

Present Status

At least 14 barley cultivars having an apparent superior protein quality as judged by the content of the essential amono acid lysine have been reported to date. For the most part, these barleys have seeds smaller than the parent of sisterline barleys which in some instances is associated with a shrunken endosperm. Glacier Ac38 has a slightly smaller seed than Glacier (46.9 vs. 49.0 mg) but is not shrunken. Shrunken Betzes (seg 1 seg 1) occured as a spontaneous mutant in the variety Betzes (Jarvi and Eslick, 1975). Based on pairs grown in 18 environments, the Betzes mutant has a higher protein and higher percentage of lysine in the barley and in the protein than its normal isotype. The shrunken mutant also has more also has more hordein in its protein. Shrunken mutants of the cultivars Glacier, Compana and Ingrid have also been found at the Montana Station and have higher lysine than the normal (R.F. Eslick, personal communication).

The discovery of Hiproly barley (Hagberg and Karlson, 1969 and Munck et al. (1969) is as well known as the finding of Opaque-2 corn by Mertz et al. (1964). It is also well recognized that the high-lysine character of Hiproly is associated with shrunken endosperm trait. The high-lysine trait is due to a single recessive gene (Munck et al. 1970) or a linked gene complex (Karlson, 1972) located on chromosome 7. The gene increases the lysine level (g/16g N) in the seed by approximately 30%. Hiproly does not exhibit the normal negative relationship of Kjeldahl protein and lysine percentage but rather shows a near linear increase in lysine (g/16g N) with increased protein (Munck et al. 1969). The high-lysine trait is also associated with a reduction in the hordein content of the barley protein.

The superior nutritive quality of Hyproly barley as suggested by the amino acid composition has been confirmed with mice (Munck et al. 1970), rats (Munck et al. 1970 and Newman et al. 1974) and pigs (Thomke and Widstromer 1975 and Newman et al. 1977). The high-lysine

trait of Hyproly has been transferred to other barleys (Munck et al. 1970) and the superior nutritive quality of the cross lines was confirmed with rats and growing pigs (Thomke and Widstromer, 1975 and Madsen et. al. 1973).

Merritt (1976) described a barley with an amylose content of approximately 44% of the total starch. This barley was designated Glacier Ac38 since it was shown to be a mutant of the 6-rowed variety Glacier (CI 9676). In addition to the starch mutation, Glacier Ac38 has approximately 8.0% more lysine (g/16g N) than Glacier (Pomeranz et al. 1972).

Two barley mutants expressing 20 to 40% more lysine than the parent were developed by chemical treatment of the variety NP-113 (Bansal, 1970). They are identified as Notch-1 and Notch-2 due to the uniform depression on the dorsal side of the seed.

Viuf (1972) using the negative relationship of crude protein and the amide content of barley protein located the high-lysine cultivar CI 7115. This barley is reported to display an increased lysine content of about 15%, compared to normal barley and resembles Hiproly in that the lysine content is rather constant at various nitrogen levels (Ingversen et al. 1973b).

These cultivars and mutants were exciting discoveries in the early phase of research on barley protein quality. The discovery of the Bomi mutant, Riso 1508 (Ingversen et al. 1973a) has completely overshadowed the earlier findings. According to these authors, mutant 1508 was found in 1970 in the Danish 2-rowed spring variety Bomi treated with ethyleneimine. The lysine content of the protein varied from 5.18 to 5.42% in four replications compared to 3.64 to 3.82% in Bomi. A 36% increase in threonine was found along with a considerable increase in histidine, aspartic acid, glycine and alanine. Glutamic acid and proline and to a lesser extent, cystine and phenilalanine were decreased compared to the parent Bomi. Albumines and globulines increased from 27% in Bomi to 46% in the protein of Bomi Riso mutant 1508 while prolamines decreased from 28 in Bomi to 9% in the mutant 1508. Glutelin was not altered. The lysine content of the prolamines and of the glutelins were 192 and 36% above the respective value for the pareht while the amino acid composition of the mutant albumin-globulin fraction is similar to that of Bomi. The mutant is further characterized by an 8% reduction in seed size and a reduction in yield per unit area of approximately 17%.

In addition to the Bomi Riso mutant 1508, 14 mutants have been discovered from mutagenically treated material according to Doll et al. (1974). These have 10 to 30% more lysine in the seed protein than the parent varieties. The 30% lysine increase in Bomi Riso mutant 1508 is due to a single recessive gene (Doll, 1973).

Carlsberg II was treated with ethyl methanesulphonate to produce two high-lysine mutants, Carlsberg Riso mutant 29 and Carlsberg Riso mutant 86 (Doll, 1972). These cultivars showed an increase of 15% in lysine and a 13 to 19% decrease in yield, respectively. A third Carlsberg Riso mutant was produced through gamma radiation that possessed a 20% increase in lysine but suffered a 23% decrease in yield compared to the parent barley. This mutant was designated Carlsberg Riso mutant 56.

Barley is reported to contain 58 to 64% starch on a dry matter basis. (Harris, 1962) and usually contains amylopectine and amylose in a 3:1 ratio, respectively.

The ratio is genetically controlled (Cameron, 1947) although it does deviate as in Glacier Ac38. Kasiwada (1930) reported on the glutinous or waxy character (wx) in barley and its inheritance. The waxy cultivar, Wapana (MT 294318) was the increase of waxy segregates from a waxy Orderbrucker (CI 7715)/7* Compana (CI 5438)F3 population. Orderbrucker is the donor parent for the waxy character and Compana recurs seven times in the pedigree. Wapana is described by Goering et al. (1973) as having nearly 100% branched chain starch molecules. The waxy starch granule appears to have fractures and either contains a small amount of amylose or long amylopectine branches (Goering et al. 1973). These authors also found the starch of Wapana to be easily hydrolysed by alpha-amylase suggesting that it might be more digestible than normal starch in mammals and birds.

Nutritional Evaluation of Barleys at the Montana Station

Our approach to nutrient evaluation of barleys includes both chemical and animal assay procedures. We are concerned with starch type, protein composition, amino acid profile and how these measurements correlate to animal performance. The albino rat is used in our laboratory as a test animal and the pig has been used where sufficient barley was available.

As previously noted, we have investigated Hiproly chemically and with both rats and pigs. We are convinced of its superior protein quality and feed value for monogastric animals. The serious limitations of this cultivar are its well known poor agronomic type and low comparative yields. We have compared numerous other barley cultivars in our laboratory and in animal feeding trials. These include barleys that are grown commercially in the Northwestern United States as well as experimental cultivars and isogenic lines.

We have fed the Compana-waxy Compana isotypes and Glacier and Glacier Ac38 barleys to both rats and pigs. We have also screened approximately 2500 2-rowed barleys for high lysine-types. Our tentative findings in the laboratory and through rat feeding trials suggest that we have found at least one relatively high lysine 2-rowed cultivar that possesses good agronomic characteristics. We are also presently studying the Bomi Riso and Carlsberg Riso mutants. The following report will summarize our findings with Wapana, Glacier Ac38, selected 2-row barleys and the Riso mutants.

Wapana, Compana, Glacier and Glacier Ac38

Starch was water extracted from Wapana, Compana, Glacier Ac38 and Glacier barleys and purified by filtration and centrifugation. Isonitrogenous 15% protein nutritionally balanced diets were prepared with starches and casein. Diets were fed to weanling rats in a 28-day growth trial. Two nitrogen and energy balance trials were completed using the 15% protein diets in the first trial and 10% protein diets in a second.

Average gain in the growth trial was higher ($P < .10$) in rats fed the glacier starch diet as compared to rats fed the Compana or Glacier Ac38 starch diets although there were no differences in feed consumption or feed efficiency. Rats fed Wapana starch did not differ from rats fed the other three starches for average gain or protein efficiency ratio (PER). Glacier and Compana starch diets produced a higher ($P < .05$) PER as compared to the starch from Glacier Ac38 but were not different from Wapana diets in this respect.

More nitrogen was digested by rats fed Wapana starch ($P < .01$) than rats fed the Compana or Glacier Ac38 starches in 15% protein diets while the rats fed Glacier starch were not different from the other three starches in this regard. In the second trial (10% protein diets) the Glacier Ac38 starch diet was lowest ($P < .01$) in digestible nitrogen when compared to the other three diets. No differences were

observed in retained nitrogen or digestable energy between starch types in either bakance trial.

Three pairs of Wapana and Compana were grown in adjoining plots at 3 locations. In one pair, Compana contained 3 percentage points less protein and 34% less lysine in the whole kernel. Otherwise there were no differences in approximate composition of the barleys. Average lysine in the Compana and Wapana barley proteins was 3.45 and 3.34% respectively. Isonitrogenous 10.5% protein diets were prepared from each barley and fed to weanling rats. Those rats fed Wapana tended to eat less which was reflected in a slower rate of gain although the differences were not significant. Feed efficiency, PER or nitrogen and energy balance was not affected by barley type. Two feeding trials were conducted to compare Wapana and Compana as cereals in diets of growing pigs. Vitamine-mineral fortified diets were prepared with and without supplemental soybean meal. Thirty two pigs were fed in each trial with eight pigs per diet. Pigs fed soy supplemented diets grew faster ($P < .01$) in both trials. There was no differences in rate of gain or feed efficiency due to barley where diets contained soybean meal,; however, in the second trial pigs fed Wapana without soy gained faster ($P < .01$). The unsupplemented Wapana diet producing the faster gain contained approximately 3 percentage points more total protein than the Compana, whereas protein levels between barleys were identical in the first trial. Feed efficiency tended to favor the Compana diets with the exception of the higher protein unsupplemented Wapana diet (Trial 2) but differences were not significant ($P < .05$). Barley type had no effect on carcass development within protein levels.

Three pairs of Glacier Ac38 and Glacier barleys were grown in adjoining plots in 3 locations. Proximate analysis were same for the two barley types within location. Amino acid analysis revealed approximately 8% more lysine in Glacier Ac38 accompanied by an increase in Arginine, threonine and tryptophan. Glacier Ac38 contained less ($P < .05$) proline and Glutamic acid than Glacier. Protein fractionation of these barleys and two more pairs of Glacier Ac38 and Glacier indicated approximately 3 percentage points less hordien and glutelins and an increase in Albumine + Globulin fractions in Glacier Ac38. Percentage of Kjeldahl protein and percentage of hordein in the protein of these barleys were highly ($P < .01$) correlated ($r = .91$). Albumin + Globulin and the glutelin fractions were less correlated with percentage protein and showed a negative relationship ($r = -.45$ and $-.47$, respectively. Lysine was negatively correlated ($P < .05$) with percentage protein ($r = -.73$).

Four pairs of Glacier Ac38 and Glacier barleys were fed in isonitrogenous diets to weanling rats. Glacier Ac38 produced the greatest gain ($P<.01$) and highest PER ($P<.05$). Two nitrogen-energy balance trials with rats indicated more digestible energy ($P<.01$) and nitrogen ($P<.01$) in Glacier than in Glacier Ac38. Biological values for these barleys have not been determined.

Pigs fed soybean meal supplemented Glacier Ac38 and Glacier diets gained at an equal rate in two trials, however, feed utilization was best ($P<.05$) in pigs fed Glacier. The barley pair was fed without supplemental protein in a third trial. Rate of gain was the same for both barleys, although pigs fed Glacier Ac38 ate less feed ($P<.10$) which resulted in greater feed utilization ($P<.10$) by pigs fed the mutant. Carcass leanness tended to favor pigs in the Glacier Ac38 group, but all differences were not significant.

Selected 2-Rowed Barleys

Eighteen cultivars were selected for their percentage lysine (g/16g N) from a collection of 2-rowed barleys using the DBC method of Mossberg (1969). These barleys along with Hiproly were compared in our laboratory through chemical analysis and in rat growth and metabolism trials.

Kjeldahl protein (dry matter basis) in the eighteen barleys exclusive of Hiproly ranged from 11.9 to 15.9% (avg 14.4%) in the seed and from 14.2 to 18.0% (avg 16.1%) in the progeny. The lysine (g/16g N) ranged from 3.67 to 4.04% (avg 3.88%) in the seed and from 3.41 to 3.97% (avg 3.71%) in the progeny. Percentage lysine in the seed and progeny was significantly correlated ($P<.01$) $r=.72$). A negative relationship existed between the percentage lysine and the Kjeldahl protein, $r=-.72$. The percentage of albumine + globulin, hordein and glutelin in the barley protein was determined in the 18 barleys, Hiproly and four commercial varieties. The salt soluble protein (albumine + globulins) ranged from a minimum of 27.5% in Wapana to 39.8% in Hanna. The hordein ranged from a minimum of 17.2% in Italian barley to a maximum of 36.9% in Wapana. The glutelin ranged from 23.6% in Ci 12099 to 36.3% in Unitan. SDS disc gel electrophoresis indicated the existance of 6, 5 and 5 types of component combinations in albumine + globulin, hordein and glutelin, respectively. The concentration of components comparable in molecular weights varied considerably.

In the rat growth trial, five of the barleys produced gains that were not different ($P<.05$) from gains of rats fed the casein control diet. These were Hanna (CI 906), Balder (CI 7131), CI 10375, Brage (CI 11310) and Hiproly. These barleys also produced the highest PERs and lowest feed/gain ratios, although differences were not significant in all instances. Hiproly was the best of the barleys in terms of gain, feed efficiency and PER followed by Hanna, Balder and Brage.

Differences between these four barleys as measured by rat performance were not significant. Compana produced the slowest gain, poorest feed efficiency and lowest PER.

The five barleys with the highest PER were compared in a metabolism trial with five barleys having the lowest PER Imperial (CI 13827) The average PER of the five high-PER and five low-PER barleys were 1.96 and 1.66, respectively. The biological value (BV) of Hiproly was higher ($P<.05$) than that of Imperial and Wapana. True digestible protein (TDP) of Compana was higher ($P<.05$) than that of Hanna, Balder, CI 10375, Hiproly and CI 12171. Net protein utilization did not differ ($P<.05$) between barleys. Composite means of high-PER and low-PER barleys were different for BV and TPD ($P<.01$) and also for net protein utilization (NPU) ($P<.10$). A negative relationship appeared to have occured between the high and low-PER barleys for BV and TPD.

The average BV of the high-PER barleys was higher ($P<.01$) than that of the low-PER barleys (68.3 vs. 61.4%) and the average TPD of the high-PER barleys was lower ($P<.01$) than that of the low-PER barleys (75.7 vs. 79.3%). The NPU was higher ($P<.05$) for the high-PER barleys.

Protein efficiency ratios obtained in the growth trial were positively correlated ($P<.01$) with BV ($r=.81$) but were negatively correlated ($P<.01$) with TPD ($r=-.73$). The percentage of lysine was positively correlated ($r=.71$) (.05) with BV but was negatively correlated ($r=-.60$) ($P<.05$) with TPD. Tyrosine showed the highest correlation with TPD ($r=.77$) ($P<.05$). Each amino acid tested exhibited the opposite relationship with BV and TPD, as with lysine and tyrosine, although most r values were not significant.

A stepwise multiple regression analysis was computed with the percentage of amino acids (g/16g N) as the independent variable and rate of gain, feed intake, feed efficiency and PER as dependent variables.

Lysine was the single most important amino acid for all measurments; R^2 of lysine for gain, intake, efficiency and PER were .508, .648, and .699, respectively. The next two most important amino acids were tryptophan and isoleucine in that order for gain, intake and efficiency and in reverse order for PER. Arginine, threonin and histidine followed in order of importance for gain and intake but histidine was reversed with threonine in the case of efficiency. After lysine, isoleucine and tryptophan for PER, tyrosine, glysine and treonine followed in order of importance. These data, indicated that the three most important amino acids in this group of barleys for efficient growth of weanling rats were lysine, isoeucine and tryptophan.

Seven of the barleys representing high, medium and low PERs were replanted to compare the barleys is a second crop year. Barleys chosen and PERs were respectively: Hanna, 1.96, CI 10375, 1.94; Balder, 1,92; Brage, 1.83; CI 12103, 1.85; Bargiers, 1.77; and Compana, 1.59. Amino acid analyses of each barley were comparable between the original seed and the two successive crop years. Hiproly and Brage were not different in respect to PER and both had significantly ($P < .05$) higher PERs than the other five barleys. Protein efficiency rations of the other five barleys appeared to be similar. Hanna had the highest BV followed by Balder, CI 12103, Brage, CI 10375, Compana and Bargiers in that order. Balder analyzed 3.90, 3.97 and 3.92% lysine (g/16 g N) and Brage analyzed 3.77, 3.96 and 3.95% lysine (g/16 g N) in three successive years. Hanna, Balder and Brage produced PERs that were lower but not significantly different from that of Hiproly in one feeding trial and Brage was not different from Hiproly in this respect in a second feeding trial.

Riso Mutants

Five mutants of Bomi and two mutants of Carlsberg II and Hiproly and Hiproly Normal were compared chemically and in rat growth trials. Biological value and TPD were measured in a metabolism trial on the Hiproly isotypes, Bomi and the Bomi Riso mutants. Average Kjeldahl protein of the five Bomi mutants were essentially the same as the parent barley Bomi (13.5 vs. 13.4%) on a dry matter basis. The Carlsberg II mutants were higher in Kjeldahl protein than Carlsberg II (12.9 vs. 11.4%). The percentage of protein in the Hiproly and Hiproly Normal pair was consistent with previous determinations (20.6 and 17.9%, respectively).

All of the Riso mutants showed a significant increase (12 to 56% in percentage lysine over the parent Bomi and Carlsberg II with the exception of Bomi Riso mutant 9. A rise in percentage lysine was accompanied by a decrease in the percentage of glutamic acid and proline in the barley proteins. Arginine, Threonine and the two nonessential amino acids, alanine and aspartic acid, appeared to be increased in the mutant barley proteins. Bomi Riso mutant 1508 evidenced the greatest percentage increase (55.6%) of lysine over the parent followed by the Bomi Riso 8 (32.5%) and Bomi Riso 13 (30.5%) mutants.

Fractionation of the protein from Bomi Riso mutant 1508 indicated variance due to location. The percentage of hordeins in two samples were identical (15%) and had similar levels of the salt soluble albumine+ Globulin fractions (45 and 49%). The third sample of the Bomi Riso Mutant 1508 had only 5% hordein and showed an increase in the albumine+ globulin fraction (55%). The Bomis did not vary in this respect but contained considerable more hordein and less of the albumine + globulin fraction than did the samples of mutant 1508. The two samples containing the 15% hordein had approximately 25% plump kernels while the sample having 5% hordein had less than 1% plump kernels. The protein of the latter sample contained 5.60% lysine and the former samples contained 4.41 and 4.45% lysine, respectively. A negative correlation ($r=-.79$) (P .05) was found between the percentage of hordein and the percentage of lysine in the kernel protein of these barleys.

The Bomi Riso mutants 7, 8 and 13 showed a trend similar to the Bomi Riso mutant 1508 in respect to percentage of hordein and albumine+ globulin fractions. The Carlsberg Riso mutants exhibited a decrease in hordein and an increase in albumine+globulin compared to the parent Carlsberg II. There was less difference in the fractions between Hiproly and Hiproly Normal as compared to the Riso mutants, however, Hiproly possessed the greater percentage of albumine+globulin and smaller percentage of hordeins as compared to Hiproly Normal. Hiproly contained more hordein and less albumine + globulin than did either Bomi or Carlsberg II.

Rats fed Bomi Riso mutant 1508 and Carlsberg II riso mutant 56 gained equally as well and produced PER values that were not different from the PER of rats fed cassein. Bomi mutants 7 and 1508 produced PER values significantly higher than Bomi ($P<.05$). The Bomi Riso mutant 9 which had the lowest percentage of lysine produced the slowest gain, poorest feed efficiency and lowest PER in the comparison. Although rats fed the Carlsberg II mutants gained faster ($P<.05$) than rats fed the parent Carlsberg II, only mutant 56 produced a PER higher ($P<.05$) than the parent barley.

Two growth trials were conducted with weanling rats to compare high-lysine maize and normal maize to the Bomi Riso mutant 1508 and to the Carlsberg II Riso mutants 29 and 86. High-lysine maize produced greater PERs ($P < .05$) than any of the Riso mutants, although the mutants and parent barleys were superior ($P < .05$) to normal maize. Mutant 1508 was superior to Bomi ($P < .05$) in PER value and the Carlsberg II Riso mutant 86 was superior to Carlsberg II in this regard.

Carlsberg II produced a lower PER than the mutant 29, but differences were not significant.

Biological value of the mutant and parent barley proteins were correlated with the percentage of lysine ($r=-.86$). A negative correlation was found to exist between TPD and percentage lysine ($r=-.84$) and between BV and TPD ($r=-.80$). The Bomi Riso mutants 1508 and 8 had the highest BV of the barleys compared, 91.7 and 91.6%, respectively. The parent barley, Bomi, was equivalent to Hiproly in BV (73.8 vs. 69.3%, respectively) in addition to comparable performance in the growth trial.

A stepwise multiple regression revealed that lysine was the most important amino acid for gain, PER and BV.

Concluding Remarks

Protein quality in barley has been achieved through careful selection and screening programs. The importance of protein quality in animal nutrition can be readily applied to human nutrition. The need for quality protein by the children of this generation and the generations to come should not be forgotten in favour of an appetite satiated with calories and poor quality protein.

Minor genes may ultimately be as important in developing superior quality protein in barley as the major genes. It is evident that more than one gene exists that controls amino acid and protein components in barley and it is quite probable that somewhere there are synergistic genes for high-lysine, high protein and high yields. Intensive research and development is the answer to agro-engineering a barley that does not compromise nutritive quality for yield, nor yield for nitritive quality.

Summary

A screening program using the DBC method has identified one or two barley cultivars that may have superior food quality as determined by essential amino acids, PER and BV measurements. Balder (CI 7131) and Brage (CI 11310) were shown to contain nearly 4.00% lysine (g/16g N) in successive crop years. The lysine content of 23 2-rowed barleys was correlated ($P < .01$) to gain, feed efficiency and PER and was less related to feed intake. Barley lysine and BV were positively correlated but lysine exhibited a negative correlation with TPD. Stepwise multiple regression indicated lysine to be the most important amino acid for gain, intake, feed efficiency and PER followed by tryptophan and isoleucine.

Five mutants of Bomi and two mutants of Carlsberg II, Hiproly, Hiproly Normal, maize and high-lysine maize were compared chemically and in rat growth and metabolism trials. The mutants showed a significant increase (12 to 56%) in percentage lysine over the parent barleys with the exception of Bomi Riso mutant 9. Rats fed Bomi Riso mutant 1508 and Carlsberg II Riso mutant 56 gained equally as well and produced PER values that were not different (P .05) from the PER of rats fed casein. The BV of Bomi Riso mutant 1508 was 124% of that of Bomi ($P < .01$). Carlsberg II mutants were similar to the Riso mutant 1508 in BV but only 100% of that of Carlsberg II.

Acknowledgments

The data presented are in part the research findings of C.C. Calvert, D.K. Stutz and J.Stobart in partial fulfilment of the requirements for the M.S. degree. The author is also indebted to Professor Robert F. Eslick for his suggestions and propogation of the barleys. Others who have contributed to the data presented are: Dr. B.R. Moss, Dr. A.M. El-Negoumy, Dr. Charles McGuire, Mrs. Shirley Gerhard, Mrs. Nancy Roth, Mrs. Dana Leininger and Mr. Don McCarl. This research was supported by the U.S. AID contract ta-c-1094 and the Montana Agricultural Experiment Station.

REFERENCES

Bansal, H.C. 1970. A new mutant induced in barley. Current Sci. 39:494.

Cameron, J.W. 1974. Chemico-genetic bases for reserve carbohydrate in maize endosperm. Genetics 34:459.

Doll, H. 1972. Variation in protein quantity and quality induced in barley by EMS treatment: Induced mutations and plant improvement. Proc. Study Group Meeting, Buenos Aires, IAEA, Vienna, 331.

Doll, H. 1973. Inheritance of the high-lysine character of a barley mutant. Hereditas 74:293.

Doll, H.B. Koie and B.O. Eggum. 1974. Induced high-lysine barley mutants. Radiation Botany 14:73.

Frey, K.J. 1973. Improvement of quantity and quality of cereal grain protein. In: Alternate sources of protein for animal production. National Academy Sci. ISBN 0-309-2114-6, Washington, D.C.

Goering, K.G., R.F. Eslick and B.W. DeHaas. 1973. Barley starch V. A comparison of the properties of waxy Compana barley starch with the starch of its parents. Cereal Chem. 50:322.

Hagberg, A. and K-E. Karlsson. 1969. New approaches to breeding for improved plant protein: Breeding for high protein content in barley. IAEA Vienna STI Pub. 212:17.

Harris, G. 1962. The structural chemistry of barley and malt. In:A.H. Cook (ed) Barley and Malt, p. 431, Oxford.

Ingversen, J., B. Koie and H. Doll. 1973a. Induced seed protein mutant of barley. Experientia 29:1151.

Ingversen, J., A.J. Anderson, H. Doll and B. Koie. 1973b. Selection and properties of high lysine barley. Nuclear Techniques for seed improvement IAEA, Vienna.

Jarvi, A.J. and R.F. Eslick. 1975. Shrunken endosperm mutants in barley. Crop Sci. 15:363.

Karlsson, K - E. 1972. Linkage studies on a gene for high lysine content in Hiproly barley. Barley Genetics Newsletter 2:34.

Kasiwada, S. 1930. On the glutinous and starchy barley and its inheritance. Crop Sci. Soc. Japan, Proc. 2:193.

Madsen, A., H.P. Mortensen, A.E. Larsen and B.T. Viuf. 1973. Byg med forskelligt proteinindhold og proteinkvalitet. Landokonomisk Forsogs laboratoriums efterarsmode, Arbog P. 75.

Mertz, E.T., L.S. Bates and O.E. Nelson. 1964. Mutant gene that changes protein composition and increases lysine content of maize endosperm. Science 145:279.

Mossberg, R. 1969. Evaluation of protein quality and quantity by dyebinding capacity: A tool in plant breeding. In: New approaches to breeding for improved plant protein. IAEA, Vienna STI Pub. 212. p. 151-160.

Merritt, N.R. 1967. A new strain of barley with starch of high amylose content. J. Inst, Brwing (London) 73:583.

Munck, L. 1970. Increasing and nutritional value in cereal protein - Basis research on the Hily character. In: Improving plant protein by Nuclear techniques, IAEA FAO, Vienna, STI Pub. 258, p 319 - 330.

Munck, L., K-E. Karlsson and A. Hagberg. 1969. Genetics of Quality-Feeding Value. Barley Genetics II Symposium, Wash. State Univ. Pullman.

Munck, L., K-E. Karlsson, A. Hagberg and B.O. Eggum. 1970 Gene for improved nutritional value in barley seed protein. Science 168:985.

Newman, C.W., R.F. Eslick and R.C. Rasmuson. 1974. Effect of barley variety on protein quality and nutritional value for rats. J. Animal Sci. 38:71.

Newman, C.W., R.F. Eslick, B.R. Moss and A.M. El-Negoumy. 1977. Hiproly barley as a source of protein and amino acids for growing-finishing pigs. Nutrition Reports International. (In press).

Pomeranz, Y. 1975. Proteins and amino acids of barley, oats and buckwheat. In: M. Friedman (ed) Protein Nutritional Quality of Foods and Feeds, part 2, Marcel Dekker, Inc. N.Y.

Pomeranz, Y., R.F. Eslick and G.S. Robbins. 1972. Amino acid composition and malting and brewing performance of high-amylose and Hiproly barleys. Cereal Chem. 49:629.

Thomke, S.O.S. and B. Widstromer. 1975. Nutritional evaluation of high lysine barley fed to pigs In: M. Friedman (ed) Protein Nutritional Quality of Foods and Feeds, part 2. Marcel Dekker, Inc. N.Y.

Viuf, B, Toft. 1972 Varietal differences in nitrogen content and protein quality in barley, Kgl. Veterinaer og Landbohojshole, Arsskrift 37.

Whitehouse, R.N.H. 1973. The potential of cereal grain crops for protein production. In: J.G.W. Jones (ed) The Biological Efficiency of Protein Production. Cambridge University Press.

BARLEY AS FOOD IN OLD SCANDINAVIA ESPECIALLY DENMARK

By

Lars Munck*

In joining a workshop where barley for food is discussed, I asked myself what I knew about this topic ? In spite of 17 years of study of the nutritional quality of barley I found I was not acquainted with barley for food except for beer. I therefore asked ICARDA to coordinate and collect recipes from the participants of this symposium to fill in our gap of knowledge. As plant breeders we should know how to prepare good food from barley, and the relating food preparation and nutritive factors which we could control in our breeding work.

In the bronze age, barley was extensively grown in Scandinavia (about 2000 B.C.). It was not until later that rye and oats were introduced. Wheat was much more sensitive to the cold climate so barley became the major cereal for food. A tradition which has lasted in Denmark to the last century. The menu in the beginning of the 1900 in Lunnede on the Island of Fyn could be examplified as follows:

Morning: Porridge of barley grits cooked in milk or beer.
Noon : Meatsoup with abraded barley.
Evening: Porridge of barley cooked in enough amounts to have the extra warmed in the next morning.

It is hard to find tests in the scientific literature where human subjects have been tested on barley. The history may speak for itself. The people who survived on this monotonous barley diet would be proof that barley is a valuable food. However, Professor M. Hindhede came in his book (Fuldkommen Sundhed og vejen dertil, Kobenhavn 1934) to my help. I now want to cite his results to prove to you that barley really is THE NUTRIENT.

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* Carlsberg Research Laboratory, Denmark.

Seven Experiments with Barley Grits (Page 106)

On the 19th of August 1914 a trial with barley porridge cooked in water was commenced with Mr. Fr. Madsen as the research subject. The porridge was eaten with sugar and a small amount of margarine. Commencing on the 23rd of August a second research subject, Mr. Lindemoe began on the same diet.

The trial period for Mr. Madsen was 15 periods of 12 days or at the time a total of 180 days. For Mr. Lindemoe, the time was 10 x 12 equal to 120 days. The composition of the diet is shown in the following table.

In the case of the initial trial periods both fruits and milk were given in addition to the barley porridge to eliminate the possible risk of Beri-Beri or scurvy on a diet consisting only of dehusked barley grain, margarin and sugar.

As the trials continued both the research subjects found that there was no need for the additive of fruit and milk to sustain their weight. As a result of this the addition of the fruit to the diet was stopped. The nutritive content of the diet was high e. g. the following contents of digestible matter was recorded - see Table 1.

Summing up the diet was high in calories but low in protein. Mr. Madsen in this period carried out a large amount of hard work and his caloric requirement was high. During the trial periods 10-14 he was called for military service in a company of engineering troops. The company had its camp 8 kilometers outside Copenhagen. The work carried out by the engineering company was the digging of trenches. Since it was important not to interrupt the research series an explanation to Mr. Madsen's captain found a complete understanding for the research. Mr. Madsen was given a special pass which in spite of the rules of the camp allowed him to stay outside until one o'clock at night. The work of Mr. Madsen in the camp was on a work done basis. Because of his incredibly high work tempo, he finished the days quota of work in the morning before noon so that he could cycle to Copenhagen and be in the laboratory to have his first meal of the day between 12 and 1 o'clock. He then carried out his normal work in the laboratory, eat his barley porridge in the evening and cycled back at mid-night to the camp.

As the series of trials occurred in January and February, and as the winter is usually cold at that time the unique ability of Mr. Madsen, I suspect nobody out of 1000 could have done the same way. It was also a convincing proof for the value of barley porridge as a nutritive element. As far as his ability to work and his general humor was concerned, there is present the following declaration from his officers:

"Jagersborg d. 20/4/1915.
To Dr. Hindhede
Dear Sir:
Madsen, pioneer no. 56 has over the last month and a half under the hardest winter months carried out heavy digging work for me. In spite of his strange way of life he has shown an excellent work capability, energy and durability. He is always amongst the pioneers that I chose when special difficult tasks have to be delegated. Madsen has always been in the best humor.

Copenhagen - d. 21/4/1915. Kai Ulrich
Second Leutenant

I can fully endorse the above declaration from second leutenant Kai Ulrich concerning Madsen. Pioneer 56 and his work in January, February and March 1915. Madsen has always been one of the best workers in the company.

T. J. Helsted
Captain of Engineers
Chief for the Sixth Engineering Company"

Concerning Mr. Madsen's weight, the following comments should be made. Apart from the fall in weight during the first research periods Mr. Madsen's weight was constant during the whole research time. The loss of 4 kilos in the first period can be easily explained. This period occurred immediately after a month's holiday during which Mr. Madsen ate an undefined diet. Although during the holidays he also ate vegetarian foods, the transition from the varied diet to a monotonous research diet in general induces a fall in weight. This transition is not pleasant and results in a low calorie intake - only 2700 calories - during the first period. When he became accustomed to the diet the calorie intake increased and there was no further fall in weight.

Mr. Lindemoe was from the beginning of the trial period in a state of poor health. He had a stomach problem and wished for a prescription of medicine to aid for this. As the researcher, I explained to him that he had come to the wrong man as I did not believe in prescription. I informed him that since he had just had started a series of nutritional research with barley porridge I believed that this diet would help his stomach problems and I further said to him that if he was interested his diet would be free. Mr. Lindemoe agreed to go along with the trial and in the beginning of February I presented him personally in a meeting of the Royal Danish Domestic Science Society. This man who, in August, appeared bleak and unhealthy arose to the podium with a rosy face and explained "I have now lived on barley porridge for the last five months. As well as having completely recovered my health I have also put on 18 pounds ".

Barley porridge has for hundreds of years been the national food for Denmark. As a child in the countryside we eat barley porridge 2-3 times a day. Although dehulled wheat as a sole diet results in beri-beri symptoms, dehulled barley does not produce these symptoms and must therefore contain larger amounts of B-Vitamines within the seed. So ends Professor Hindhede story on nutritional studies.

Because in the future we will need increasing amounts of food I think its a good idea for us as plant breeders to start early consideration of the functional food acceptability factors and their nutritive quality. We have much to learn from the past but also we need new discovery. We must also make new nutritive and tasteful dishes.

It is well known that as much as 50% fine barley meal could be added to wheat meal to make a tasty bread. However, it tends to dry out quicker than normal wheat bread. In Norway and Sweden there is a tradition for hard thin bread baked on the stone in an oven. In the old days this bread was made almost entirely from barley and it was dried and kept up to six months as a staple food.

In the Faroe-Islands the local six-row barley was milled and made into dough balls which were placed on the open fire in order to form a crust. Then the balls were kept in the warm ash to mature. This ancient type of bread was called drylur. In Dalarne, Sweden, peameal, bark meal (the phloem) and oats were blended into the barley meal for baking. Beer was usually sour and bad but was very often used in food preparation, often in bread making.

Abraded barley seeds and barley grits were used in soups or as porridge. Barley meal was often cooked in clumbs together with pork as a spice. Grits and meal were also cooked in a cloth or with animal guts as sausages with various spices and animal blood.

I have selected the following recipes which gives a representative picture how barley was used in Denmark. The amylose-amylopectin ratio which regulates the water absorption and viscosity of starch must be one of the outstanding functional factors in making barley food useful. The work on rice may provide us with a valuable parallel.

I thank my colleagues Tine Olesen, Lise Tang Petersen and Gregory Gibbons in their help in arranging this material.

Table I. Experiment with barley grits M. Hindhede 1934.
Figures intake per day.

Fr. Madsen (test subject)

No. Periods 12 days	Barley g	Margarine g	Sugar g	Fruit g	Milk cc	Weight kg
						80
1	667	58				76
2	750	67	83		500	74
3	750	67	125	2000		76
4	750	67	125	2000		76
5	750	67	125	1000		76.5
6	833	100	167			76
7	792	100	167			76
8	752	100	167			76.5
9	833	108	183			76.5
10-14	806	103	210			
15	917	83	125			76
Lindemoe (test subject)						
						63.5
1	500	75	125	200		63
2	667	133	167	1350		65.5
3	703	150	200	750		68
4	667	125	217			69
5	600	125	225			70.5
6	500	204	150			70.5
7	542	125	100			73.5
8	542	125	125			74.5
9	550	119	180			73.5
10	417	108	137			72.5

Content of Nutrients

Subject	Protein g	Fat g	Carbohydrates g	Calories g
Fr. Madsen	60	89	752	4256
Lindemoe	40	110	682	4065

OLD DANISH BARLEY FOODS:

Bread from fine Barley meal

1 kilo fine barley meal
0.7 liter butter or skim milk
70 gram yeast
20 g salt - water

Fermentation 20 minutes at 25°C then the dough is struck together with a spoon and fermented 15 minutes in a baking form. It is baked at 200°C for one hour.

Knepkager - tickcakes

2 pounds barleymeal
1 pound butter or fat
2-3 eggs
a little sugar
some cream
some ammonim carbonate
water

The dough is flattened out and cut with a wooden form with a nice ornament making prints on the cake. They are smirred with eggs and cream which have been whipped. They are baked in an oven. The cakes are making a ticky noise in the oven.

Barley Porridge

Abraded barley grains 500 gram
circa 3 litre, water or milk
salt

The porridge is cooked 2-3 hours. Could be spiced with dried raisins to be added 30 minutes before finishing.

Blood Pudding

4 litre blood
1 kilo fine barley grits
0.5 kilo crude ryemeal
3 litre milk
250 g pig fat
250 g raisins
0.5 kilo brown sugar
25 g cinnamon
25 g cloves
3 spoons of salt
some Thyme

The Barley and rye meal is put in the blood to soak over night. The fat is fried and the milk is cooked with the Thyme and all ingredients added together. It is heated until it begins to stiffen. The mass is put in cakeforms and cooked in water bath in the oven for two hours.

Barley Pancake

0.5 kilo barleymeal
2 eggs
1 spoon brown sugar
1 spoon yeast
1/2 spoon cinnamon
citruspeels
0.5 litre milk

The ingredients are mixed and fermented for two hours. They are baked as pancakes

Sour Porridge

2 litre Buttermilk
325 grams abraded whole barley

The seeds are soaked in buttermilk overnight. They are cooked and kept warm without cooking for two hours in a hotbox. They are cooked again while they are agitated vigorously for a long time. It is eaten with milk, syrup or butter. The old national dish of Western Jutland

Barley Soup

1.5 litre water
75 grams barley grits
80 grams dried plums without stone
75 grams raisins
90 grams elderberry juice
60 grams sugar

The barley grits are steeped overnight and is then cooked three hours - then the other ingredients are added except juice and sugar which is added just before serving.

CONCLUDING REMARKS

INTERNATIONAL AND REGIONAL NURSERIES

By

J. P. Srivastava *

From the 30 different barley programs in the region outlined during the course of this Symposium it is obvious that there are only a few countries in which well developed barley improvement programs exist. There appears to be a general lack of skilled manpower, research facilities, availability of diverse germplasm and incentives for barley research and production. In view of the fact that barley is more efficient as compared to wheat under moisture stress conditions, is the only crop that can be grown in some areas and is traditionally the poor man's food crop, greater attention and resources than applied at present are required to improve its productivity.

In this session, international centers and organizations and some national programs engaged in distribution of wheat and barley germplasm and training of personnel presented the salient features of their research activities as related to wheat and barley improvement.

Dr. L.R. Morsi outlined the work of the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) in carrying out field trials on agronomic practices and crop rotations suitable for low rainfall areas throughout the Arab States. He stressed ACSAD's emphasis on increased involvement of the national programs in further tests on rotations, cultural practices and agronomy in addition to the breeding aspects. Some observation lines and F_2 populations were distributed to member states for local selection.

Dr. Anderson indicated that CIMMYT's barley breeding program was directed towards developing food and feed barley varieties for the areas outside the high rainfall belts of the world, and in the higher altitudes which have a short growing season and where wheat is ill-adapted. Four types of nurseries are currently being distributed by CIMMYT:

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* Plant Breeder, Cereals Improvement,
International Center for Agricultural Research in the Dry Areas
P.O.Box 5466 - Aleppo, Syrian Arab Republic

1. F_2's from various crosses
2. The international barley observation nursery (IBON)
3. Crossing blocks (CB)
4. The elite barley yield trials (EBYT).

The development of agronomically superior lines with high nutritional quality is underway and considerable progress in increasing yielding ability was reported. Incorporation of disease resistance, increased straw strength and early maturity has also been possible in many lines and it was felt that these may prove suitable for the Arid highland and mountainous regions of the world.

The regional program of the FAO has played a very important role in upgrading the research capabilities of the region by the provision of training, expert staff, research facilities and germplasm. Dr. Klaimi informed us that FAO has built up a network of cooperative testing together with other international and national agencies operating in the region.

Dr. H.S. Darling, outlined the objectives of ICARDA and its activities in the region. He informed the group that ICARDA would continue to strengthen its barley research, germplasm development and distribution activities and would be providing considerably greater training opportunities to the region. He emphasized the need for close cooperation between the international agencies and the programs involved in improving cereal production in the region. Five types of barley nurseries prepared jointly with CIMMYT are currently distributed to national programs as part of this effort. These are as follows:

1. Regional Disease and Insect Screening Nursery (RDISN)
2. Preliminary Observation Nursery (PON)
3. Regional Barley Yield Trial (RBYT)
4. Regional Crossing Block (RCB)
5. Segregating Populations (SP's)

Dr. L.P. Carter outlined the Montana State University - USAID Barley Research Program. Barley Improvement Research has been conducted at Montana State University since 1894. The Agency for International Development supported project "Improvement of the

nutritive quality and productivity of barley for semi-arid regions" began in May 1974. The major target areas for the application of research findings are the rainfed areas of developing countries which include the Middle East, North Africa and Asia. The project will in cooperation with other international centers, survey target countries to evaluate cultivars for general agronomic characteristics, utilization and disease pest problems and will involve extensive exchange of germplasm and information.

In his presentation, Dr. J.G.Moseman reported that the USDA barley germplasm collection now has approximately 20,000 accessions. He outlined the main objective of this program which is to furnish genetically diverse barley germplasm to plant breeders and other scientists interested in barley improvement. The accessions are obtained from plant explorers, curators, breeders and other scientists, and seed is distributed free for experimental use to all individuals, institutions or organizations interested in barley improvement.

Dr. Arne Hagberg emphasized that food and feed value has received high priority in the plant breeding programs at the Svalof breeding center. The lysine improvement program in barley which has achieved considerable success was outlined together with the current work on the lysine variation in barley, wheat, and triticale which is explored, identified, genetically studied and used in the breeding programs. The cooperative program with FAO involving the training of young barley workers in barley breeding and nutritional quality was also described.

Dr. Kingma described the off-season winter cereal nursery facility in Kenya that provides valuable service to winter cereal breeders in the Middle East and North Africa. This facility provided by the Ministry of Agriculture, Government of Kenya at the National Plant Breeding Institute Njoro, in cooperation with CIMMYT, it was explained as the dual advantages of advancing breeding material by one generation and disease screening which make it an important component of the overall program.

Dr. W.L.McCuistion outlined the objectives of the International Winter Spring Wheat Program at Oregon State University, which also includes Winter/Spring Crosses in barley and triticales. Both malting and feed grain barleys are receiving strong emphasis in this effort.

Dr. K.D.Wilhelmi described the objectives, observations and results of the International Winter Wheat Performance Nursery (IWWPN) coordinated by the University of Nebraska and the Agricultural Service of the USDA. He outlined the primary objective of the IWWPN which is to obtain information on the adaptation and performance of Winter Wheat Varieties, and the group was informed that through this nursery several varieties possessing excellent yields combined with other desirable traits have been identified.

Conclusion

It can be seen from some countries, European and American programs and the International Centers that there has been considerable progress in the work of barley breeding and production management in recent years. Most of the countries of the region are interested in strengthening their barley research work and there is an increasing willingness on the part of those countries with more experience and germplasm to make these resources more freely available. Such a transfer of relevant information from and between national and international programs would greatly enhance the process of increasing research and production competence and of developing the germplasm bases of the less advanced programs. Increased opportunities for training of barley personnel, exchange of scientists and a free flow of information and germplasm would be further advantages stemming from this increased cooperation among research efforts within and outside the region.

EVALUATION OF ACTIVITIES IN THE AREAS OF MANAGEMENT AND CULTURAL PRACTICES

By

R. A. Nilan *

From the papers presented, related tours and contacts made during the conference, I am convinced that there is a tremendous potential for increasing yields and quality of barley in the North African, Middle Eastern, and Southern European region. In fact, it appears that yield increases of 25-50% may be eventually obtained.

To realize this potential three major developments are definitely required:

1) There must be an extensive education program among growers concerning the differences between barley and wheat in the important plant characteristics and production practices. Most growers are more familiar with wheat than with barley production, and the advice they receive and use relates more to wheat than barley. In many areas of the region, especially of those with lower rainfall, barley will out-yield wheat. Growers must be educated to capitalize on barley's uniqueness and its uses as described in this conference by Wright and Skorda. In short, the "second class" status of barley in the region must be eliminated.

   Growers must be urged to modernize farm practices and avoid old and traditional practices that have been developed for wheat, but are not necessarily best for barley.

2) Growers must be directed to use improved varieties as described in the breeding papers and summarized by Dr. Hagberg. In this connection, high quality seed supplies as described by Douglas is essential.

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3) Finally, growers must be educated towards improvement in management and cultural practices. This must be done by demonstration and through considerably more effort. Improvements in management and cultural practices will produce (a) higher yields in marginal soils and under low rainfall where barley is often relegated, (b) higher yields over the whole area with the new varieties, (c) better quality of the grain, and (d) less pest and winter kill damage.

The various management and cultural practices that can be considered will be briefly outlined here. Some of them are obvious and require very little technical knowledge and background. Indeed, they could be put into practice now with resulting increases in yield per acre.

Seed Bed Preparation

Optimum seed bed preparation which is conducted on land that has been involved in an appropriate rotation is essential. Some likely rotations were discussed by Doolette. In some areas fallow is essential to conserve sufficient moisture. The pH of the soil must be increased to avoid aluminium toxicity. In my part of the world "no till" has been quite successful as a prevention for soil erosion by wind or water and as a means of conserving moisture. Each time the soil is worked before planting a certain amount of moisture will be lost.

Improved tillage practices will improve soil, nutrition, water, and soil conservation and utilization, provide more plant nutrient uptake and more efficient growth and yield. As barley becomes a more profitable crop, growers will be able to use increasing amounts of chemical fertilizers which will lead to increased yields.

Seed Treatment

Seed treatment with chemicals may be important in some areas. However, this practice must be handled judiciously.

Rate of Seeding

Hadjichristodoulou adequately presented information concerning the important effects of rate of seeding on barley. His and other data indicate there is an optimum rate of seeding for different regions with different varieties. Too high a rate may produce too many tillers, and if the plants come under too much stress, poor grain-fill will result. Too low a rate of seeding will produce too few plants for optimum yields. Remember that most barley varieties, especially those developed within recent years, tiller well. However, varietal differences exist for this

trait. At Pullman winter barley fields with winter survival of 60% and above will tiller sufficiently to produce about a 100% stand and a normal yield. A uniform rate of seeding will also improve yields.

Date of Seeding

Date of seeding is one of the most important cultural practices with barley and one that can be readily adjusted for optimum yields. From reports at this meeting and observations at some of the trials, it is obvious that the general trend in the Mediterranean region is to plant too late. This is often because growers will plant wheat first.

Barley should be planted as early as possible, often in relation to rainfall distribution as discussed by Bronzi. Barley matures earlier and early seeding utilizes moisture and avoids hot weather during pollination. Also by planting early disease and insect, especially aphid, attacks can be avoided and the barley can be harvested before the wheat crop. We find in our area that earlier planting of barley in the fall reduces winter kill.

The best time to plant throughout the Mediterranean region appears to be November 15 or earlier. Many barley fields and trials we visited were planted in December which is too late.

Depth of Seeding

Depth of seeding may also be important in connection with drought resistance (Morsi and Quhaiwi) and winter survival - although Hadjichristodoulou warned depths beyond 5-10 cm should be avoided with some varieties. Barley, as described by Wright, sets the crown node and secondary root system at a greater depth than wheat. Thus, for many varieties the secondary roots can be into moisture, whereas if they were set higher they would be in dry soil. Furthermore, such varieties will tend to be more winter tolerant.

In summary, eventually it should be possible to provide "recipes" for date, rate, and depth of seeding for each variety to obtain maximum yields and food and feed quality.

Weed Control

Weed control was discussed by Nelson and Saghir. From these reports it is clear that weeds are one of the main problems in obtaining optimum yields from current varieties in this region. As barley becomes a more profitable crop and more chemical herbicides can be purchased, higher yields should result.

Saghir indicated that we may eventually need herbicide resistance in barley plants in order to utilize herbicides more effectively. At my University and elsewhere some attention is being given to selecting herbicide resistant barleys among either induced mutants or natural germplasm sources.

Harvesting

Harvesting practices probably can be improved to increase yield. For instance, there is often a tendency to harvest wheat before barley. When the ripe barley remains in the field too long, spikes will be lost and yields will be reduced.

Conclusion

Obviously much more research and education is required in this region to realize the potential yields of current and new varieties of barley. Eventually it will be possible to develop "recipes" for different varieties in terms of producing maximum yields and food and feed quality in the various areas of the region. However, it appears that even smaller increments of effort in this direction will produce considerable returns.

CONCLUDING REMARKS - CROP IMPROVEMENT

By

A. Hagberg*

It is quite clear to us from the country reports that there has been a good deal of progress in the work of barley breeding in this region. There is now established in most countries a fairly good working program. The build up of the breeding programs and the breeding material suited for the area is a long term job. It is also a costly one and it certainly needs support of different kinds.

In the process of building germplasm it is important to use the experience which has been achieved in different areas of the world. We should bring this information together and help each other. I am happy to see such a good effort here in this workshop.

This workshop devoted a special session to breeding problems. Drs Rasmussen, Jenkins and Ramage have given us an excellent survey of the problems that barley breeders are facing I recommend for further study of these papers when the workshop proceedings are printed. Barley breeding can be divided in three types of projects. First, those which have an immediate pay-off, those which have a short term pay-off and those which have a long term pay-off. I think what we should be dealing with, are programs of the first type in this region, i.e. the immediate pay-off. The long term projects should be taken care of by the well established breeding centers and they should cooperate with the national institutions in the region.

The rapid development of new improved varieties for the different barley growing areas within the region, is an important and necessary goal. Time is limited and the breeding process should move as fast as possible. That means we should try to speed up advancement and grow more than one generation per year. Also we should start early selections and F_3 bulking

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should be sufficient. The breeding procedures should allow for as much recombination as possible to increase variability.

We have been hearing from Bob Eslick and others that it may be possible to break linkages which have remained unbroken for a long time. I think this is a very necessary problem to look into, but I am not sure that we can break them all just by conventional means. This subject is more of a long term project. We should also exploit haploids, single seed descent and winter by spring habit crosses to further increase new recombinations.

The use of male sterility genes in the selection cycles has been presented and intensively discussed. They may be very useful in certain breeding programs depending on the design of the breeding goals. Of course, it is not a solution to every problem.

One of the most important decisions in breeding is in the choice of the parents. This requires good knowledge of the material available and also the experience of systematical studying crosses. This may be a field where experience from the different established breeding centers could be pooled and made available to new breeding institutes. Of course, there should also be a distribution of composite crosses and some are already available. We have seen some of those distributed by Ramage on our field trip.

Priority of breeding goals is very important problem. The number of characters which we should be interested in working with should be cut down or restricted. We learned from Rasmussen that the more characters we add to the selection process the more slowly will be the progress.

From the point of production, I think we have to consider the improvement in the yield first. There is no doubt that this is to all of us, the number one goal. It will be necessary to introduce the genetic base for high yielding potential and to combine this with characters from locally adapted types. We should have in mind the yielding potential as the most important objective in this project.

Varieties for certain areas need tolerance to stress of different kinds. Drought resistance for instance, we have seen in a very drastic form on the field trip. Heat tolerance and tolerance to diseases are of course also very important problems.

Earliness has been dealt with and there might be different kinds of reactions to early ripening, depending on the area where the varieties are grown. One paper referred to dealing with light intensity, I would rather call it photoperiodic sensitivity. I can tell you that the variety Mari in this area is very early in ripening but it is very late if you grow it up at the Artic Circle. If you come to the south of Sweden the first Mari is only about 3-4 days later. If you come to Spain it is three weeks earlier and if you take it down to the Canary Islands it is one and a half months earlier. So you have very drastic effect of a simply controlled genetic factor in the variety Mari and it is reacting completely different from the motherline Bonus.

In the efforts to produce earliness and high yield we have been interested in crossing 6 rows x 2 row barleys. There have been many disappointments but I think that a backcross program may be successfully used. Not only for the 6-row barleys which are generally earlier but also in the 2-row barleys. One or two back-crosses provide a good possibility to exploit. Of course, you should be careful that you have pure 6-row or a pure 2-row types. I believe you can transfer good yields from either of them. This has been our experience anyway.

As to the quality it is quite clear that brewers desire a special quality. However, it is difficult for the breeders to combine all of the desirable characters. When you are marketing a good malting barley very often you will find that you are also concerned with the highest yielding variety as well. That may differ from region to region.

I don't know if it can be stated generally, but it is easier to produce a high productive barley and transfer into it the malting and brewering qualities. The process of developing a special barley for malting only is difficult.

Anyway, in the new programs in this region there should be a strong emphasis on the nutritional value that has been mentioned several times. The possibilities are good for improving food and feed value with the present available materials. Conventional fact says a feed barley is not too good for malting. Yesterday a comment was made that a good feed barley may have some of the same characteristics as the good malting barley. This factor needs to be explored.

It is not only the genetic composition of the barley varieties that is important but their availability is just as important. It is strongly recommended that the countries in this region should not take steps to enter into the plant breeders right system. This is a system which has cost lots of extra effort to European breeders. In trying to meet the requirements outlined often breeding work is more of a cosmetic breeding effect rather than true progress toward increasing production. For this reason I think we should try to keep the market open and to have as much exchange and cooperation as possible in the breeding programs. We should make full use also of the International Organizations for breeding and genetics. We have a number of organizations doing a good job of exchanging germplasm. This is an area which will be touched by Dr. Srivastava later on. Thank you very much.

ECONOMIC POLICIES, SEED PRODUCTION AND TRANSFER OF TECHNOLOGIES

By

S. Barghouti*

The presentations and discussions on these subjects have, of course, raised more questions than they have answered. Discussions have centred round the thesis...

'that Barley is produced in lower quality soils, under less favourable conditions and probably by less progressive farmers than is wheat'.

We do not know how correct this is, but given the statement as a starting point we must first of all turn our attention towards the patterns of barley consumption in the region.

Once these patterns of consumption have been identified and the demand and potential demand for barley made clear we can then move forward in improvement work with a full knowledge of what we need to develop the crop for. If the conditions under which barley is produced really are harsher than those for wheat then we have to be concerned with evolving a technological package which assures stability of production as this is vitally important in the more marginal areas. To achieve this stability we require agronomic practices in the farmers' fields that assure the stable supply of his need. The prices that farmers receive for their products are determined through the market place by consumption patterns and so a prerequisite for these stable needs is a stable market. As Dr. Winkelman pointed out, an increase in the production of barley for malting or field purposes may not result in significant price fluctuations. But an increase for human consumption will cause a drastic price reduction as this market is very limited. Such a fluctuation may make it hard for the farmer, even with this higher level of production, to achieve that stable level of his needs. We must be very aware of this when determining the strategy to be used for increasing production.

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This strategy is also dependant on the kind of technology introduced as was discussed by Dr. Mann. He raised the question of how we should view the development and transfer of the technological package, whether as a closed box or as groups of elements or clusters. Farmers, it was explained, will not necessarily adopt the package as a whole but will select those elements which seem technically and economically more feasable, given their own perceptions of risk and productivity. Although we all agree that the technology package is very valuable for extension work we must be concerned that both agronomists and economists work together in identifying those aspects of the package which are fundamentally more important in given situations.

A third major factor bearing on the evolution of a production strategy, namely, the state of development of institutions for the production and distribution of seeds of improved varieties (both basic and commercial), was highlighted by Dr. Douglas. His survey painted a black picture of the present state of such institutions and facilities. In seven out of ten countries in the region no institutions exist and in all eight out of the ten countries that do have some sort of facility this is the responsibility of the public sector and may often not produce the seed varieties required. There is, therefore, a great need to find ways of stimulating the countries of the region to give priority to the development of institutions for the production of cereal seed in general and barley in particular.

The problem of barley is particularly significant if we take the original hypothesis that barley is at present produced on poor soils under poor conditions by poor farmers, as being correct. These farmers are out of reach of the commercial sector which is responsible for seed and other input distribution. A special sector network of services should be established to serve this part of the farming community so that the improved varieties and technologies produced for these harsher conditions can be brought to those areas where they are really needed and where they will make a real and lasting impact.

PLANT PROTECTION

By

E.E. Saari*

In the case of barley not much work has been done in terms of plant protection in this region, particularly, when you compare this with North America and Europe. I presume that this lack of attention in plant protection is a reflection of the environment where barley is cultivated. In this area barley is sown predominantly in the marginal sites and in the low rainfall areas. As a consequence, the plant protection needs have not been as demanding as in Europe and North America, where barley is grown in much higher rainfall areas. These needs have forced a more active program in the breeding for disease and insect resistance. The net result is that the plant protection, in the form of built in "genetic insurance", is far ahead in North America and Europe.

There is without question, plenty of barley diseases - I mean in the numerical sense in this region. The most often encountered and serious are those caused by fungi. There are relatively few bacterial problems that are significant at this time. The number of recognized virus diseases are few. The fact that virus problems seem to be insignificant is rather an interesting feature. It may reflect our uneducated eye, and the fact that "you are obvious only after you have been discovered". I think there needs to be a conscious effort to not become sterio-typed in our thinking as to what is present or not in the area. We are aware that in other areas virus diseases are major problems in barley production.

Insects are usually a more serious problem in barley as compared with wheat. There seems to be a higher damage level in barley, or at least the visual appearance of damage is more predominant. This aspect is a subject that needs to be documented much more closely.

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Nematodes are also a problem in some areas. In some soils Heterodera avenae for example, can be very destructive to barley. Incorporation of resistance is possible and crop rotation can be useful in minimizing damage from this pest.

Birds are another problem, especially on barley. This topic has been debated over the table on more than one occasion and attempts to control birds in the field has failed on more than one occasion. It is a difficult problem to address, because the only successful way that I know of achieving bird control would be unacceptable to many. Our greatest success in minimizing bird damage has resulted when we have used a combination of noise making carbide type guns with the presence of an actual shot-gun which is used periodically. The practice has been to employ a watchman with a shot-gun and he is allowed to shoot 15 to 20 shells each day. The addition of carbide guns in the field seem to confuse the birds which cannot distinguish between the two and seem to stay weary and away from the crop. This at least works for experimental fields when surrounding commercial fields remain unattended.

Storage problems, I do not think that should be an issue for the improvement side of plant protection. I believe that storage is primarily a management issue. I hate to see wasted effort in breeding for storage resistance. By the application of good management practices storage problems can be minimized. Some expertise will be required of course in cases where fumigation is required. Plant protection personnel can contribute in this area and must carry out evaluation on procedures and efficiency.

I think that, now, there is a need to continue to search for sources of resistance. In this part of the world the diversity of barley, because it is the center of origin, provides a unique opportunity to identify lines which can be useful for barley breeding throughout the world. We need to continue building-up our germplasm base for both disease and insect resistance. As we identify resistance we need to continue our screening efforts in order to improve our overall levels of resistance. The development of multiple disease and insect resistant varieties is an important area requiring additional attention. This subject is a long term and difficult committment, but we need to initiate greater efforts in this area.

We will also need to continue our surveillance efforts. There is a need to establish values on the frequencies of disease and insect attacks, determine the magnitude of their importance and to establish probability values for each of the diseases and insect problems. Such information would help to assign research priorities. I think that this type of research efforts needs to be placed on a continuing basis. On the whole, I think there is a great deal of room for barley improvement. Plant protection efforts can provide a major contribution towards these increases in barley production.

GENERAL CONCLUSIONS OF THE WORKSHOP

By

R. G. Anderson

It seems that in many of the countries of the region barley is traditionally treated as an inferior crop both by the farmers and by the policy makers. Farmers will generally only grow barley where they are unable to grow any other crop and little encouragement is given by the policy makers for increased barley production. A possible exception to this is the production of malting varieties which usually receives considerable support.

There are some areas in the region where only barley can be grown and where it is consequently important. However, these areas are very marginal and hence any improvement may not be very significant.

The discussions during the workshop have centered on the following areas:

(a) Barley Breeding

It has been stressed that research efforts should be concentrated on varietal development in the first instance.

Of the many different programs from the region represented at this meeting some have considerable resources, in terms of skilled manpower and facilities available to them while others have only very limited resources. With this situation in view it was felt that much of the basic work should be left to those organisations with highly developed improvement facilities. A close collaboration between all the programs

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involved would then enable the weaker partners to gain from the stronger, so that all concerned would be able to produce through adaptive research the varieties that are required in their own areas.

(b) Agronomic and Cultural Practices

Most of the varieties available at present have sufficient genetic potentials to give much higher yields than are being obtained. In many of the countries of the region the main factors limiting the adequate expression of these potentials are outmoded cultural practices. As has been well illustrated in Turkey, the improvement of cultural practices such as weed control and fertilizer usage can result in a rapid and substantial increase in yields. This is of prime importance if we are to really increase the food production and standard of living in the countries of the region.

(c) Disease Control

Discussions on this topic have illustrated the wide extent and scope of the disease information dissemination system which is now being operated in the region. This also provides for varieties to be tested for resistance through exposure to a wide disease spectrum over a very large area. It enables the evolution of varieties possessing a strong broad based type of resistance active over a considerable area instead of the limited race specific type of resistance which has been favoured up until recently. Resistance of this form gives varieties a much longer lifespan and increases their yield stability, a factor of great importance, especially in more marginal areas.

For this type of operation to be effective and successful increased cooperation between every organisation in the field will be necessary, so that all information and improved material is freely available and accessible.

(d) International Programs

We have learned much about the state of many international programs during this conference. They are providing

a vital collaborative channel for information and material between the national programs, the regional institutions and the international centres. This type of cooperation is vital to the preservation of a mobile pool of genes and knowledge to which every collaborator has easy access.

The international system is unique in being able to provide this sort of service and we must build onto this to achieve a much closer and more effective network both within and between the regions concerned.

(e) Economic Considerations

The need for a production package of materials and farming practices applicable for specific conditions has been made clear. However, we must realise that such packages have to be made flexible as agriculture is in a continuing state of evolution and all specific farm situations vary considerably.

It will also be necessary for the governments of the countries concerned to play an active part so that the appropriate inputs are available to the farmers at the right time. Without this cooperation it is unlikely that the introduction of the new technologies will prove effective.

(f) Seed Production

An active organization for seed production and bulking of new varieties is sadly lacking in the majority of the countries of the region. In the few countries that do have a seed production organization it is primarily concerned with wheat. The absence of such a system is a great hindrance to the introduction and spread of the new varieties produced in the research organizations, especially as it is an area outside the responsibility of the researcher. There is a need to move forward aggressively and to solve this problem. The main responsibility for providing an opportunity for a viable seed industry rests with the individual governments.

Of the ways of dealing with the development of a seed production effort, I feel that a system of contracting farmers to grow the seed would be preferable to systems involving laws or royalties, as these tend to be restrictive. However, I hope that whatever methods are necessary and effective can be taken to ensure that the work of the researchers is brought to the places it is required. This should be done efficiently and with the minimum of delay so that a real impact can be made in increasing the food production of the region.

CLOSING ADDRESS

(In Summary Form)

By

Subhi Qasem*

I would like to express on behalf of the Ministry of Agriculture, the University of Jordan, Faculty of Agriculture and everyone here the great sense of pride that we feel in hosting this gathering of distinguished scientists and workers. Those who have been working throughout their lives silently and diligently towards the improvement of world food production and making this world a happier and more peaceful place.

A few weeks ago, in a lecture at the University, Professor Henn, a distinguished nutritionist, made the point that the nutritive needs of male humans over the age of 40 could be 90% satisfied from a cereal diet. With this knowledge and our doctors telling us that the way to health in Middle age lies through increased fibre and bran in the diet the opportunities for barley as a human food are considerably expanding. A point which has been very well illustrated by Mrs.Saari's excellent barley snacks.

On the other hand we hear of continuing advances in the utilisation of wood shavings and industrial by-products for animal feedstuffs. Thereby making great economies in the use of barley in this sector. This, coupled with the progressive decline in the working animal population, further reducing barley feed requirements, will I think provide an increasing opportunity for barley to be diverted into feeds for human consumption. Especially as I hear that the Soviet Union is encouraging a switch in tastes from vodka to beer amongst its people, a fact which alone should considerably increase the world demand for malting Barley.

I am sure that this distinguished group has chosen the theme of this conference with an increasing awareness of these trends.

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* Dean, Faculty of Agriculture, University of Jordan, Amman, Jordan.

We have been shown evidence that barley can compete favourably with alternative crops not only in the more marginal areas but also in those areas traditionally favoured for crop production. It is now time for barley, which has been discriminated against so much in the past, especially in developing countries, to achieve the importance it deserves in World Food Production.

I feel that this conference, by chosing barley as its theme will greatly assist in the publicising of the crop and enhance its chances of becoming a future major focus for policy planners in terms of a human food.

This conference has highlighted many problem areas which will require much continued research, but it has revealed the tremendous volume of technology that has been developed and information that is now available throughout the world on this crop with its great potential.

The time has come for farmers and policy makers throughout the world, especially in the developing countries, to commit themselves to overcoming the barrier to the acceptance of barley as an economic alternative crop, existing in many parts of the world today. It is up to us to make use of the continuing evolution of technology packages and information that has been made available by our distinguished colleagues and put it to work for the cause of human welfare.

I would also like to address these remarks as a thank you to the many people who have done as much to make this conference a success.

I do not want to list names as I understand that Mr. Carter is about to do just that, but I must thank you all for giving us the pleasure and the honour of your presence with us here in Amman these past few days.

STATEMENT OF APPRECIATION

By

Lark P. Carter*

It is appropriate that we express our deep appreciation to the many people who have made the conference such a success. It took the joint efforts of many people to organize, plan, arrange and assist with this program.

We are most grateful to His Royal Highness Crown Prince Hassan for giving of his time to be with us on Sunday morning for the opening session. His presence gave a dignity to the conference that got us off to a good start.

We also express our appreciation to His Excellency the President of the University of Jordan for making this facility available to the conference and for hosting the fine dinner for participants on Monday night.

Our gratitude is extended also to His Excellency the Minister of Agriculture for welcoming us to Amman and also for hosting a delicious dinner for us on Sunday night. To Deputy Minister of Agriculture, Mr. Said Ghezawi, we owe special thanks for making available a large number of his staff and facilities of the Ministry of Agriculture for this conference and for his continuing support on our behalf.

We are especially grateful to Dr. Subhi Qasem, Dean of Agriculture at the University of Jordan and his staff. Without their support and many efforts this conference could not have been such a success. Dr. Qasem worked very hard making the necessary arrangements, often working behind the scene to assure a smooth operation. He has been a most gracious host.

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Mr. Ghosheh, Dr. Duwayri, Mr. Nabil Katkhuda and their staff spent many long hours preparing for this conference and performed many services to assure our comfort and to supply things needed for the conference. They also made arrangements for a very interesting and informative field trip on Tuesday. We appreciated the efforts of all of these people and express our gratitude to them.

To Ola Hammad we express our thanks for her unfailing support in helping to organize this conference. Also she and Mrs. Bronzi are to be recognized and thanked for arranging an interesting and much appreciated program for the wives of participants.

Our thanks also to Norman Calder, who has handled the financial side of the workshop and thus provided for our subsistance.

We also express our thanks to the Royal Jordanian Army Band for a magnificant performance for the conference participants on Wednesday evening. This colorful and precisely executed concert was enjoyed and appreciated by all.

We must recognize the untiring efforts of Afaf Rashed, Nada Khattar and Naila Hamza who handled questions, assisted with airline reservations, took care of necessary typing of abstracts, programs, etc., and all of the countless other things that go with making the conference run smoothly. Our sincere thanks to all three of them.

Our thanks are also expressed to all who served as session chairmen, reports and to all participants for preparing and presenting the many papers. Also a thank you to the other people who gave of their time and energy to assist with this conference and to make our stay here so pleasant.

We all owe to Jit Srivastava, Shawki Barghouti and Gene Saari a special recognition and expression of gratitude for the many things they did to assure a smooth running and productive conference. They have worked very hard to assure a successful conference and we are most grateful.

Also to Mrs. Saari and Mrs. Hawtin we express our thanks for developing the barley recipe book and for preparing barley product snacks for the coffee breaks. They were very good.

You may be interested in knowing the members of program planning committee; Dr. Jit Srivastava, Dr. Glenn Anderson and myself (Dr. L. P. Carter). We met last year to make a general plan for the conference. Special recognition must go to Dr. Srivastava who put the final touches on the program.

The sponsors of the conference were ICARDA, CIMMYT and the Montana State University USAID project.

Finally to all our hosts, the Government of Jordan, the Ministry of Agriculture, the University of Jordan and the Faculty of Agriculture, we extend our sincere thanks for an enlightening interesting and worthwhile conference.

PUBLISHED AND PRINTED

BY

The International Center For Agricultural Research In The Dry Areas

(I C A R D A)

P.O. Box 5466 . Aleppo. Syria

AND

International Maize And Wheat Improvement Center

(C I M M Y T)

El Batan – Mexico

1978