

Spring Wheat in Kazakhstan: Current Status and Future Directions



**A. Morgounov, A. Satybaldin,
S. Rajaram, and A. McNab, editors**



CIMMYT

International Maize and
Wheat Improvement Center



National Academic Center of Agricultural and
Research, Kazakhstan

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S. Rajaram, and A. McNab, editors**

**In memory of O.S. Shegebaev,
dedicated scientist and esteemed colleague**

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Opening Address

V.S. Schkolnik

Minister of Science

President of the Academy of Sciences, Almaty, Kazakstan

Dear guests and colleagues:

The Republic of Kazakstan is an important grain producer. Spring wheat constitutes 90% of total wheat production. The temperature profile, dry climate, and soil conditions in the main grain producing regions favor the production of high quality wheat grain. The quality of durum wheat varieties produced in Kazakstan was once unique in the world. The wheat of Kazakstan is highly valued on both the domestic and international markets for making bread, biscuits, and alcohol. Today the domestic market consumes only one third of Kazakstan's total wheat production; the rest is exported.

Kazakstan is a full member of the Grain Trading Committee and has the status of an observer in the International Grain Council's Committee for Food Assistance.

This is also the contribution of Kazakstan's agricultural scientists, who developed and released highly productive wheat varieties for the country's different climatic zones, organized seed production, and developed regional cultivation technologies. However, due to the strong competition on the international market, it is necessary to speed up the development and release of high yielding wheat varieties with good grain quality that are well adapted to the harsh soil and climatic conditions, pests, and diseases that prevail in our country. The quality of our bread wheat varieties must meet international standards so that we can sell Kazakstan grain on the international market.

It is not possible to solve the problems of wheat production in Kazakstan without utilizing world experience and global plant genetic

resources, and without cooperating closely with foreign scientists. This is why I support the development of a collaborative spring wheat research program with CIMMYT, which works under the auspices of the United Nations and cooperates with scientists from countries all over the world. I am confident that the participants in this international conference, including scientists from the USA, Mexico, Germany, Turkey, Russia, Uzbekistan, Kyrgyzstan, and Kazakstan, as well as the leaders of our ministries, and representatives of the World Bank, USAID, and GTZ (Germany), will successfully develop the cooperative program.

Now allow me to officially open the international conference "Current Status and Perspectives of Spring Wheat Production in Kazakstan."

Sustainable Intensification of Agriculture

T. G. Reeves,
Director General, CIMMYT

The only way for agriculture to keep pace with population and alleviate world hunger is to increase the intensity of production in those ecosystems that lend themselves to sustainable intensification while decreasing the intensity of production in the more fragile ecologies. In particular, if we fail to get agriculture moving in the African countries south of the Sahara, poverty will continue to grow, and the impending social upheavals that will ensue will become a global nightmare.

Borlaug and Dowsell (1997)

Introduction

Much has been said about the need for sustainable agriculture during the past one or two decades. Hardly a paper is written or a speech given on agriculture which does not now incorporate the word “sustainable.” This level of awareness is indeed healthy because agricultural systems that are sustainable are not only desirable, but obligatory and urgently required. However, as Alexander (1992) put it so well, “Everybody wants sustainable agriculture, but few have any idea of what it actually means, let alone how to go about achieving it.”

This challenge—to turn good ideas into reality—has been a continuing objective of agricultural science since its inception. However, the challenge of putting sustainable agricultural systems into place has perhaps seen less progress than is desired and indeed, necessary. The concept of sustainable agriculture is difficult to deal with in most countries, particularly in many developing countries, where farmers have few resources and little flexibility to change their practices, and where the risks of failure often have tragic consequences.

We have only to re-read Dr. Borlaug’s statement above to understand that it is imperative that we as scientists “get real” in our work on agricultural sustainability. It is essential that ideas on sustainability move with appropriate urgency from scientists’ and farmers’ brains, to real research programs and real farmers’ fields. It is a challenge being taken up by CIMMYT, with its partners, as we move into systems-based research, organized in multidisciplinary projects.

I believe that scientists and farmers have made real progress in some areas of agricultural sustainability. I am also highly optimistic that, with continued application and investment, there will be major developments in the next ten years or so, as biotechnology and other new tools are effectively utilized.

To achieve this accelerated development, however, new research paradigms are required. Such paradigms would effectively address whole systems; more effectively combine new technologies and traditional knowledge; and more effectively integrate farmers and communities into research,

development, and extension. This paper first outlines a few important principles of sustainable agriculture and then takes a close look at some practical approaches that we can follow to make sustainable systems a reality in farmers’ fields.

Sustainable Agriculture: What Is It?

Sustainability in agriculture is a “moving target.” No single method of farming in any region remains sustainable without continual intervention and change. Agriculture is based on dynamic biological, physical, and chemical systems, and farmers live in a constantly changing economic, social, and political environment. Given this scenario it is illogical to believe that there is a “magic bullet” to deliver sustainable agriculture to all farming locations. The reality is that sustainable farming systems can differ from field to field and from one period of time to another. What is sustainable in one place, at one time, may not be sustainable forever, which is why continued investments must be made in agricultural research and in updating farmers’ knowledge and skills. The task is never finished;

indeed, this is reflected in one of the dictionary definitions of “sustainable”:

sustainable = supportable

That is, to remain sustainable, an agricultural system must continually be supported with new knowledge, new practices, and new technology.

Whilst it is not surprising that such a complex topic as sustainability generates considerable debate and a range of widely differing opinions, the time has now come for consensus on the ways forward. Nero fiddling whilst Rome burnt, pales into insignificance compared to well-heeled experts in the North involved in never-ending academic “slanging matches” as 40,000 women, children, and men die each day in developing countries. We must move forward, and move forward collectively, each doing what we do best and putting our energies into integrating these efforts, rather than arguing as to why they are mutually exclusive, or one is right and one is wrong. Action is paramount!

One of the major recurring debates has focused on the level of inputs applicable to “sustainable agriculture.” The fact of the matter is that for a system to maintain its sustainability, the nutrients and other components removed in harvested produce or lost in the production process must be replaced to maintain balance. Accordingly, it is reasonable to assume that a range of alternatives is available at the site level, but only some options will actually be sustainable (Table 1).

For the resource-poor farmer, who often has to produce more food from less land, the temptation to “mine” the land is overwhelming. Hence the perilously low levels of soil fertility in many regions of the world, particularly sub-Saharan Africa. Many farms have shifted inexorably from high input–high output systems (when land was first cleared and millennia of soil fertility were there to be tapped) to low-high systems, and now, on all too many farms, to low-low systems. Whilst one could argue that the latter type of system is in balance, it is not sustainable. It is almost invariably not productive enough, or profitable enough, for the farming family to enjoy a reasonable standard of living or even to survive. In addition the farmer is quite naturally continuously trying to extract a higher level of output from the farm than the low or zero level of inputs can sustain. This practice, born of necessity, results in a “downward spiral” of soil fertility. It gives the farmer no scope or flexibility for diversity or sustainable rotations, as the whole farm area is required to produce the basic foodstuff, be it maize, wheat, or any other food crop.

Interventions are necessary if this downward spiral is first to be halted and then reversed. Logically, one could

argue that the interventions should be the return of the dung and urine of the humans and animals that ate the food produced from the field. At best, this is only a partial solution, as there are competing uses for animal dung, and there are social, health, and logistical issues in relation to human excreta. Whilst the return of animal dung and urine should be encouraged, other interventions are also necessary, and in many cases they will initially have to be external interventions. If we relied only on animal dung for the nitrogen needed for today’s food crop, an extra 2.6 million cattle would be needed – creating an ecological disaster (Borlaug, pers. comm.). Inorganic fertilizers frequently are the most effective, efficient, and economical intervention, if available. Fertilizers not only produce more grain, but also more residues both above and below the ground, in the form of shoots and roots. These contribute more organic matter to the soil and enhance carbon and nitrogen cycling, which in turn results in even better production of crops and residues and initiates an “upward spiral” in soil fertility (Figure 1). As the downward spiral is reversed, the opportunities for diversification, biological nitrogen fixation, and

Table 1. Input/output levels and system sustainability.

Level of inputs	Level of outputs	Sustainable?
Low	Low	Yes – but may not achieve necessary levels of production
Low	High	No – nutrient exhaustion, soil degradation
High	Low	No – soil acidification, salinization, nutrient leaching
High	High	Yes – but input sources, availability, and cost are critical

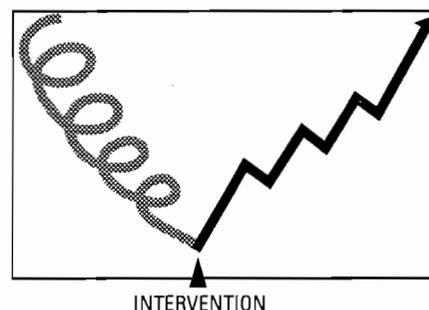


Figure 1. Reversing the “downward spiral” in soil fertility.

rotations increase geometrically. The time to intervene and break the downward spiral is now, and methods to achieve this are described in detail later in this paper.

There are many definitions of sustainable agriculture; mine is not dissimilar to most of them, except in its inclusion of political supportability as one criterion. Sustainable farming systems should be:

- economically viable;
- environmentally sound;
- socially acceptable; and
- politically supportable.

Sustainable farming systems are **economically viable** at both the farm and national levels. At the farm level, the system must produce food and income, both now and in the future. Resource-poor farmers cannot invest in systems that will not produce reasonable yields and, even better, cash income over the operational period in question. Such returns meet immediate needs and may give farmers some opportunity to invest in farm improvements that will have more enduring benefits.

At the national level, agriculture must also earn its keep as a significant contributor to GDP and export earnings. Despite the grandest visions and wishes of politicians, the reality in most developing countries is that economic well-being and development are almost invariably based initially on productive and profitable agriculture, the “engine room” of subsequent industrialization.

Sustainable farming systems are **environmentally sound**. The need to maintain and enhance the economic returns from agriculture to developing

countries, farmers, and rural communities has always been with us, but this need has probably never been of greater importance or fraught with greater uncertainty than it is today. But the complexity does not end there. As we have become increasingly aware in recent years, economic success must be achieved without unnecessary degradation of our soils, air, water, landscapes, and indigenous flora and fauna. Whilst most farmers claim to have always been cognizant of conservation issues, our greater understanding of the impact of land clearing, cultivation, overgrazing, and soil fertility changes has revealed that past intentions have differed significantly from reality. In many instances, through lack of knowledge and/or judgment, we have been profligate in our use of the basic resources of soil and water, and excessive cultivation has been one of the greatest threats to the sustainability of our soils.

The third facet of sustainable agriculture requires farming systems that are **socially acceptable**. In other words, these systems must be appropriate to the people who, relying on their own meager resources, are responsible for implementing and managing them. The need for socially acceptable systems implies the need for a better understanding of farmer and community needs and values, as well as better targeting of technology to meet local conditions.

The final facet of sustainable farming systems is really dependent on the first three. If economic growth brought about by agriculture can occur within an environmentally sound and socially acceptable

framework, then politicians will continue to view agriculture as justifying their support. The power of **political support** and the impact of enabling and facilitating policies are paramount. On the input side of agriculture, policies can make a world of difference – for example, in establishing efficient systems for placing seed, fertilizer, and credit within the reach of farmers. The same is true after the crop is harvested, when pricing, transport, storage, and marketing policies strongly influence the economics of food crop production.

All four components combine to form the whole: **sustainable agriculture**. If one is neglected, it can seriously reduce the rate and extent of progress towards sustainability.

New Research Paradigms

It is clear that if we as agriculturists are to make effective progress, we must change the way we plan, conduct, and communicate about research. Any component of a farming system can become the limiting factor to sustainability. It is therefore essential that those who work with farmers to develop sustainable systems are knowledgeable about the systems with which they work. This is not to say that everyone must be a generalist – far from it – but it is essential that highly skilled specialists such as breeders, pathologists, and socioeconomists understand the full context in which their interventions are made and the need for contributions by others. This implies a blending of research disciplines in teams of scientists seeking collective outcomes that are

appropriate and have an immediate impact in farmers' fields. It is from these fields that food supplies must come for the foreseeable future, and the farmer is the ultimate systems-oriented operator, juggling biological, economic, environmental, and social factors. In such circumstances isolated interventions can usually be of only limited value.

To more readily develop integrated solutions to complex problems, CIMMYT has adopted a new research paradigm, based on:

G	x	E	x	M	x	P
Genotype		Environment		Management		People

Whilst each of these components of an agricultural system can produce significant improvements to sustainable intensification, it is their *optimal combination* on which the new green revolution will be based. Such a combination would consist of the best variety for a given environment, incorporated into an improved soil and grown using appropriate crop management, and both the technology and the desired outcomes would be appropriate to the farming people to whom it must be effectively delivered. This paradigm is indeed a bridge between a commodity focus and an ecoregional approach.

It is essential that all who seek to foster sustainable agriculture in developing countries recognize the interdependence of these factors, because most organizations individually cannot contribute fully to each component of GxExMxP. Partnerships and consortia that assemble the best possible teams to execute the GxExMxP paradigm will underpin the timely and successful achievement of sustainable farming systems. This has major ramifications

for research and development institutions, both within and between institutions.

Many agricultural research institutions are not only structured by commodities and/or disciplines but conduct research, albeit high quality research, within these frameworks. This approach will no longer yield improvements in agricultural productivity at the rate that is urgently required. For it is not biotechnologists working alone, or plant breeders working alone, or physiologists, or agronomists alone, but their effective combination into multidisciplinary teams that will produce the desired results: beneficial impact in farmers' fields. Similarly, a straight commodity focus within, for example, a "wheat division" in an institution is unlikely to produce useful results in isolation. If a farmer has to grow wheat in a rice-wheat rotation, then it is logical that wheat researchers and rice researchers should work together to optimize the system, not each independent component of the system. The best wheat variety in a wheat-only research field may well not be the best wheat variety when it is sown late after a rice harvest – the farmer's practice.

The challenges faced within research institutions are similar to those faced between research institutions involved in the various facets of sustainable agriculture. Few organizations have the resources, skills, and knowledge to be the best at all facets of GxExMxP, but the achievement of sustainable agriculture is so urgent for the world that only the best will do. If sustainable intensification of agriculture in developing countries is

to be achieved and maintained, institutions must be willing, and must have the organizational capacity, to form effective partnerships (North/South; public/private; research/development/extension/social; and their various combinations) to which they are enthusiastically committed. At CIMMYT we believe that some internal capacity in the various aspects of the GxExMxP paradigm is critical for us to partner other key institutions effectively. We have strengthened our resources in biotechnology, economics, and sociology to build a "credible mass" of scientists with whom outside agencies would wish to work. In addition we have established a Natural Resources Group, incorporating skills in crop and soil modeling, geographic information systems (GIS), and participatory research – disciplines broadly adaptable to all regions and aspects of CIMMYT's global maize and wheat research mandate. As a result of this approach, plus the introduction of a multidisciplinary project structure, we believe that CIMMYT is effectively positioned to achieve its organizational motto: "Sustainable maize and wheat systems for the resource-poor."

The Practice of Sustainable Agricultural Systems

The exact combination of optimal management and input factors can vary from field to field and farm to farm, and generally it will vary from region to region as biophysical and socioeconomic environments change. However, extensive experience around the world – North and South – strongly indicates that a number of

practices are common to developing sustainable agricultural systems in many different situations. These practices include reduced tillage, nutrient management, rotations, integrated pest/disease/weed management, water use efficiency, and the use of appropriate and adapted crop/plant species/varieties.

Much has been written on these practices, but it is valuable to summarize their past and potential contribution to the GxExMxP research paradigm for sustainable agriculture.

Role of Genotype (G)

In feeding ourselves, are we starving our descendants? This is the question that has haunted the debate over agriculture's role in fortifying or depleting the resource base.

We believe that the answer to that question depends to a great extent on the kinds of plant varieties we develop and grow. If we set our crop breeding priorities wisely, we can develop genotypes that contribute – directly and indirectly – to sustaining the resource base.¹ These are the genotypes that will help make the GxExMxP equation truly powerful.

Two ways that genotypes can contribute – and have contributed – to conserving natural resources is through their effect on biodiversity and the stability of production. Several examples, drawn from the research of CIMMYT and its partners, are given here.

Pedigree diversity in wheat – The advantages that genetic diversity brings to a farmers' field are numerous. They include the capacity – hidden in the seed – to protect against unexpected threats, such as a new disease. This protection increases the stability of agriculture and reduces risk.

Since the early days of the Green Revolution, greater numbers of wheat varieties have been released, and many of these varieties are also more genetically diverse. As a result, genetic diversity on the farm has generally widened. Recent evidence suggests that the bread wheats that have been most widely adopted in the fields of developing country farmers also possess some of the most complex pedigrees (Smale and McBride 1996). The top ten wheat crosses grown in the developing world in 1990 are genetic powerhouses. They contain an average of 44 landraces, 19 generations, and 1,192 parental combinations in their pedigrees, of which about 20% were used only once. (For the sake of comparison, note that for all of the different crosses grown in the developing world in 1990, the average number of distinct landraces per pedigree is 36.) This gives some idea of the considerable – and continuing – investment made by farmers (landraces) and by scientific plant breeders (generations and parental combinations) in the diversity of the world's bread wheat crop.

This diversity offers additional protection against the vagaries of nature and supplements efforts by plant breeders to combat the biotic and abiotic stresses that can

transform a farmer's crop from an asset to a liability in a matter of days.

Durable disease resistance – As Byerlee (1994) has observed, one of the most underestimated ways that improved genotypes contribute to sustainability is their superior disease resistance. Improved disease resistance increases yield stability and reduces the use of pesticides, some of which are the most environmentally toxic chemicals in existence. In most of the developing world, pesticide use on wheat has been minimal, and superior disease resistance has generally substituted for the fungicides that are widely used on wheat in industrialized countries.

All of the bread wheats developed by CIMMYT possess durable resistance to stem and leaf rust (Figure 2) – traditionally two of the most damaging diseases of wheat throughout the world. CIMMYT's strategy for breeding host-plant resistance to wheat rusts is to accumulate genes from diverse sources. The geographic origins of these sources are broad, extending from North and East Africa to

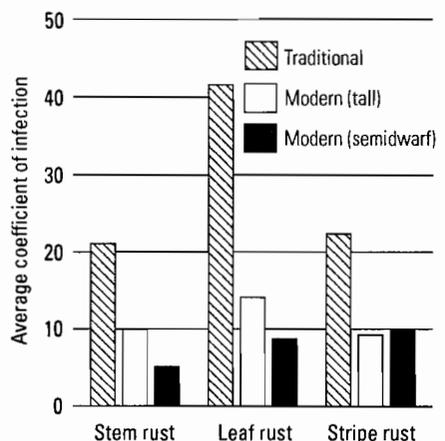


Figure 2. Rust resistance by wheat type, 50 locations in 30 countries, 1980.
Source: Rajaram et al. (1988).

¹ This section draws heavily on Byerlee (1994).

Europe, North and South America, Australia, and New Zealand (Smale and McBride 1996).

Nitrogen use efficiency in wheat – Not all of the threats to stable and sustainable yields are living organisms such as disease pathogens. Genotypes can improve the resilience of the farming system if they are bred to use resources such as soil nutrients more efficiently, and if they can tolerate abiotic stresses such as nutrient deficiencies and toxicities or drought and its accompanying problems. The potential for such germplasm to reduce input use and production costs is considerable.

CIMMYT has analyzed the input efficiency of its old and new wheat genotypes under a range of nitrogen levels, moisture regimes, and weed conditions (Figure 3). Successive varieties developed by CIMMYT and its partners, which have been grown widely in developing countries, have required less and less land and nitrogen to produce the same amount of wheat (Figure 4). Varieties developed from CIMMYT wheats can reduce the chances that too much

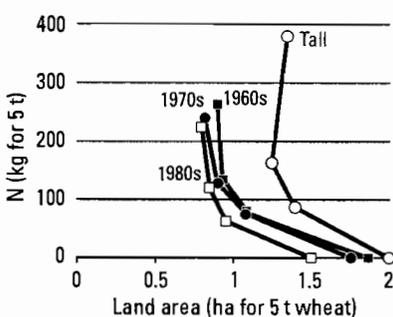


Figure 3. Kg of N required to grow 5 t of wheat. From right: Tall, two tall cultivars of 1950 and 1960; 1960s, three semidwarfs of 1962-66; 1970s, three semidwarfs of 1971-79; and 1980s, two semidwarfs of 1981 and 1985. Source: Calculated by Waggoner (1994) from data in Ortiz-Monasterio et al. (1997).

nitrogen will be used and can also make land available for alternative uses (Smale and McBride 1996). By reducing the use of nitrogen, we can also reduce the risk that this nutrient is lost in the form of air and water pollution.

Low nitrogen/drought tolerance in maize – Maize is also being bred to withstand hostile and unpredictable production environments (CIMMYT 1997).² In marginal production zones, especially in southern Africa, farmers need to make the most of two extremely scarce resources: water and nitrogen. These farmers, who harvest increasingly meager crops from increasingly depleted soils, and harvest nothing at all when the rains

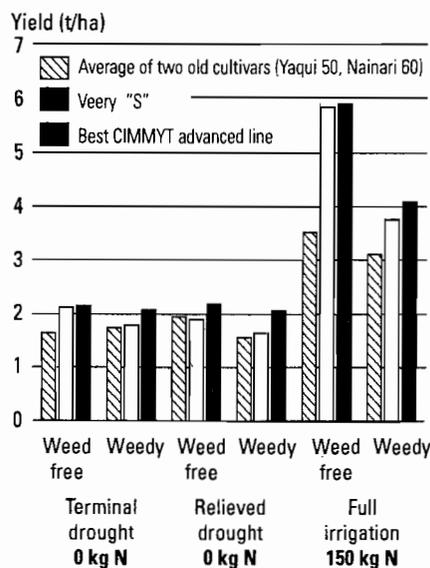


Figure 4. Input efficiency of old and new CIMMYT varieties under differing production conditions.

Source: Pfeifer and Braun (1989).

fail, are the victims of the downward spiral mentioned earlier. We have taken many steps toward helping these farmers and others in developing countries; a few of the most important steps include:

- A proven methodology for obtaining a 25-40% increase in maize yields under severe drought, with no yield penalty under good conditions. We have also discovered that selecting maize under drought confers tolerance to low nitrogen conditions.
- A global development, testing, and distribution network for maize that tolerates drought and low nitrogen.
- More than 30 elite inbred lines of tropical or subtropical adaptation that resist drought or infertile (and acid) soils, as well as insect pests, and that provide outstanding yields in hybrid combinations.
- Progress in applying molecular markers to transfer resistance traits to elite maize lines and varieties.

Like the wheat varieties described earlier, these maize genotypes contribute to sustainable agriculture by increasing yield stability, reducing the inputs needed to obtain satisfactory yields, and ensuring that repeated drought does not leave land bare – the precursor to erosion and desertification.

² This research emphasizes the earlier point that action – and real progress – to achieve sustainable systems requires collaboration. CIMMYT has not made progress in developing stress tolerant maize by working alone; this work has been supported by the United Nations Development Programme (UNDP), Swiss Development Cooperation (SDC), the International Fund for Agricultural Development (IFAD), and the Swedish International Development Cooperation Agency (Sida), and the research has also been planned and conducted in conjunction with the Maize and Wheat Improvement Research Network (MWIRNET) (funded by the European Community) the Southern African Centre for Cooperation in Agricultural Research (SACCAR), and the International Institute of Tropical Agriculture (IITA).

Acid soil tolerance in maize and wheat – Large areas of acid soils in developing countries are poorly suited for agriculture, but the development of new genotypes has made it possible for farmers to put these infertile soils to profitable use. In the case of maize, for example, researchers in Colombia and Peru have released Sikuni V-110, an acid tolerant variety developed from CIMMYT materials that yields more than 30% more than local checks on acid soils. This variety is already sown on at least 15,000 hectares. Because of new germplasm such as this, fewer farmers will be driven to open new land for agriculture after exhausting the limited potential of the land they already farm.

Summary – Appropriate varieties of maize and wheat do more than foster food security: they provide real environmental payoffs. A key aspect of improved crop varieties is that they are “embodied technologies”; they deliver sustainability in the seed. Simply by sowing the seed of a new variety, a farmer adopts the improvements that have been incorporated into it, such as better yield, enhanced nutritional quality, improved disease resistance and stress tolerance, and enhanced competition with weeds.

The probability of success may be greatest in breeding for tolerance to biotic stresses (Table 2), but as we have seen, breeders are making good progress on all fronts. Biotechnology offers even more exciting prospects for delivering germplasm that contributes to a more sustainable agriculture.

The direct contribution of improved genotypes to sustainable agriculture has been large and is easy to appreciate: higher yields with fewer inputs at less cost to the environment. However, as Byerlee (1994) has pointed out, often the most important contributions of superior maize and wheat varieties are indirect, and they are largely unrecognized in the sustainability debate:

- land-saving increases in productivity;
- poverty alleviation;
- productivity increases in favorable areas that alleviate pressure to migrate to more marginal (and often more fragile) environments (Harrington 1993); and
- productivity increases in favored areas that benefit the poor in marginal areas through lower food prices and greater employment opportunities.

These are powerful achievements, but it is instructive to remember that promising new seeds are not grown in isolation: they are grown in real places, by real people. We turn our attention next to the role of the environment in the GxExMxP paradigm.

Table 2. Prospects for developing specific traits compatible with sustainable systems, through plant breeding.

Trait	Probability of success
Insect resistance	High for most species
Pathogen resistance	High for most species
Nematode resistance	Moderate to low
Competition tolerance (e.g., weeds)	Variable
Drought tolerance	Moderate
Problem soil tolerance	Moderate
Nitrogen use efficiency	Moderate
Phosphorus use efficiency	Moderate
Root system modification	Moderate

Source: Francis (1993).

The Role of Environment (E)

Crop varieties can be replaced by farmers. However, the environments in which those varieties are grown are pretty much fixed. Important environmental variables include maximum and minimum temperature, elevation, precipitation, potential evapotranspiration, solar radiation, day length, soil pH, and other soils characteristics. What cannot be changed at least must be understood: CIMMYT is making an increased effort to understand and characterize maize and wheat production environments. Over the past couple of years, we have strengthened our capacity to conduct spatial analysis of these environments through a major renewal of our GIS laboratory. This renewal includes new hardware, new software, new datasets, new staff, and new collaborative links with both South and North.

Within the GxExMxP paradigm, an understanding of the environment factor (E) is important in addressing sustainability problems. For example, soil erosion problems are easier to solve if we know where they are concentrated. Research on management of acid soils is best guided by a knowledge of where these soils are located and what they are like, chemically and physically. And research on managing drought must be based on an understanding of what is meant by “drought,” which areas are affected, with what frequency, and with what consequences. CIMMYT’s GIS laboratory recently finished, in collaboration with CIMMYT regional staff and national program scientists in southern Africa, an environmental characterization that helped define drought, plot its incidence and

frequency, and select representative research sites for a new project aimed at developing drought-tolerant maize varieties.

Characterization of maize and wheat production environments is needed if we are to understand sustainability challenges and to target possible solutions: new varieties and improved crop, system, and resource management practices.

It is well known that the relative performance of a genotype can vary over environments. A variety that performs very well in one environment may perform poorly in one that is dissimilar (e.g., DeLacy et al. 1994). CIMMYT's Natural Resources Group is working with the Center's Maize and Wheat Programs to define "megaenvironments" — areas that cut across countries (even continents) and that have environmental characteristics similar enough to guide crop improvement. For example, CIMMYT breeders maintain that a particular kind of wheat germplasm is needed for a production environment with a mean temperature in the coolest month of over 17.5°C and lying "primarily" between 23° N and 23° S latitudes at elevations below 1,000 m. The tools of GIS are being used to help identify where in the world these conditions are prevalent in wheat systems, and which wheat research sites in which countries are most representative.

The use of megaenvironments to guide plant breeding is spatial analysis at a broad scale. However, spatial analysis also can be used at narrower scales. For example, adaptation zones for individual cultivars can be mapped out by using crop simulation models combined

with GIS (e.g., Chapman and Barreto 1994). Spatial analysis of production environments can do more than evaluate germplasm adaptation. When combined with simulation modeling it also can help target sustainable crop and system management practices to defined regions. CIMMYT's Natural Resources Group is embarking on a new project to identify those areas in Mexico and Central America best suited to sustainable maize technologies, such as green manures and conservation tillage. Efforts at adaptive and participatory research then can be targeted towards geographical areas where the technologies are biophysically well adapted and can be expected to perform well (White and Hartkamp 1998).

Similarly, simulation modeling is being used in research on risk management in drought-prone maize systems in southern Africa. Models are used to evaluate the performance of sustainable soil fertility management practices under a wide range of climate and soils conditions. Then GIS is used to see where these conditions are found (Harrington 1997).

Finally, spatial analysis of production environments can be used to add value to on-going site-level research on sustainable practices. Site similarity studies (see, for example, Hodson, Wall, and White, forthcoming) can identify other areas within a country, in a region — or even on the other side of the world — that are environmentally similar to a given research site. This helps research teams from different sites coordinate the sharing of information and gets them to think about possible extrapolation of research results. Of

course, this requires that important research sites be environmentally characterized (for example, with daily temperature, rainfall, and solar radiation data).

In the past, spatial analysis of production environments has been used to make sense at the national level of research on soil fertility (e.g., Benson 1996); identify possible areas for the introduction of new crops (e.g., Myers 1994); track land degradation in hillside systems (e.g., Pachico, Ashby, and Sanint 1994); and even organize information for setting national agricultural research priorities (e.g., Pardey and Wood 1991). It is a critical part of the GxExMxP paradigm.

The Role of Management (M)

The implementation of improved management practices on farms is likely to make the biggest contribution to agricultural sustainability during the coming decade. When combined with robust, highly productive crop varieties, it is not uncommon for such systems to double yields in farmers' fields. Dr. Borlaug (pers. comm.) has indicated that, in his current work for Sasakawa-Global 2000 in Africa, the combination of CIMMYT-derived maize germplasm with fertilizer and timely seeding and weeding has usually doubled farmers' maize yields and in some cases has resulted in increases of 200-300%. The recent maize harvests in Ethiopia have been testimony to the powerful impact of this GxM combination.

It is therefore extremely surprising that many institutions have reduced the emphasis given to agronomy research. Even in some quarters of the

Consultative Group for International Agricultural Research (CGIAR) there is a misguided belief that agronomy is not strategic research and can be left to others. This is not so. Strategic partnerships in "cutting edge" approaches to crop agronomy are as important as the alliances that are quite correctly being sought and established in biotechnology. Agronomy is no longer just about "spray and weigh" or white pegs in fields, although these are still some of the basic tools for certain kinds of agronomy research (impact in farmers' fields after all usually requires action in farmers' fields).

Strategic agronomy now involves a complex iteration of field studies, crop and soil modeling, the use of GIS, and remote sensing. The knowledge, skills, and resources required for effective, modern management research are just as significant as those necessary for biotechnology. Many aspects of agronomy and crop management can contribute to sustainable intensification of farming systems. In this paper, five key interventions are highlighted, as these interventions will be the foundation for sustainable agriculture in many parts of the world. They are:

- **Crop nutrition:** nutrient auditing and strategic fertilizer use.
- **Soil organic matter:** appropriate replenishment strategies, including green manures, crop residues, and agroforestry.
- **Crop rotations:** enhancing diversity, improving biological nitrogen fixation, serving as break crops to reduce pest problems, and allowing livestock to be integrated into the cropping system.
- **Soil tillage:** the critical role of reduced tillage and practical options for farmers.

- **Integrated pest/weed management:** the integration of resistant varieties with rotation; minimal pesticide use; role of competitive cultivars.

Crop nutrition – One of the greatest contributions to sustainability can be made by one of the simplest management interventions: the use of fertilizer to increase crop yields and enhance soil organic carbon and nitrogen cycling. Current levels of fertilizer use vary greatly between regions of the developing world (Table 3) and are particularly low in sub-Saharan Africa. An initial intervention to raise fertilizer applications can allow basic food grains to be produced on a smaller area of the farm, thereby providing some scope and flexibility for a farmer to adopt a rotation, green manuring, or some other treatment for replenishing soil fertility on the released land. Whilst there are well-recorded dangers of overuse of fertilizers (most of them in highly industrialized countries), the rates likely to be appropriate for use in developing countries are often an order of magnitude lower: 50 kg/ha in the South, for example, versus 500 kg/ha in the North!

Fertilizer use does however significantly increase economic risks for the resource-poor farmer, so it is imperative that this risk be minimized by combining strategic

Table 3. Average fertilizer use in developing countries.

Region	Nutrients (kg/ha)
Latin America	51
South and Southeast Asia	75
Sub-Saharan Africa	8
Europe and USA	121

Note: 1988/89 data.

fertilizer use with nutrient-efficient crop cultivars.

For both economic and ecological reasons, fertilizers should be used efficiently. This helps the farmer as well as the environment. Research by CIMMYT scientists has led to several means of improving fertilizer use efficiency. Our Maize Program has found that some maize varieties use nitrogen fertilizer more efficiently than others. Interestingly, these same varieties also appear to be more drought-tolerant (Edmeades et al. 1997). In Africa, research conducted by a CIMMYT-coordinated Soil Fertility Network has found that fertilizer use efficiency often can be improved by combining organic with inorganic fertilizers (Kumwenda et al. 1996). CIMMYT scientists also have found that substantial improvements in fertilizer use efficiency are feasible in rice-wheat systems in the Indo-Gangetic Plains. Helpful practices include timely sowing — made possible through conservation tillage practices (Hobbs, Ortiz-Monasterio, and Sayre 1998), forthcoming), delayed fertilizer application (Ortiz-Monasterio et al. 1994), and the use of furrow and ridge irrigation (Sayre and Moreno 1997). This means that fertilizer application rates can be slashed with no sacrifice of yields but less environmental pollution. In many areas of the world, however, fertilizers are priced out of the reach of those farmers growing foodgrains and are used only on high value crops such as coffee or tobacco. High prices may be the result of high marketing margins or merely of distorting government policies. The CIMMYT Economics Program has assessed the effects of these and other factors on the farm-level

attractiveness of fertilizer use (e.g., Harrington 1987; Heisey and Mwangi 1996; Mwangi 1996). All too often, unfortunately, the consequence is that farmers do not have a chance to try intensification strategies. So extensification runs rampant, with marginal environments falling to the plow and forests to the axe.

Soil organic matter (SOM) – Organic matter makes soil fertile, and in most situations increased SOM will help develop and maintain sustainable agricultural systems. However, efforts to increase SOM generally require considerable time, labor, and opportunity costs, and they cannot be readily achieved in the short term. For these reasons it is likely that at first many farmers will need to rely on a combination of inorganic and organic sources of soil nutrients to improve soil quality. Soil organic matter is easily lost through excessive cultivation, continuous cereal cropping, and the removal of crop residues, and it is imperative that attempts to increase SOM are maximized through complementary management practices. In the Rice-Wheat Consortium for the Indo-Gangetic Plains, for example, loss of SOM over time is thought to be one factor behind declining factor productivity (Bronson and Hobbs 1997). Diagnostic survey results suggest that farmers agree with this assessment — and reveal the changes in farm system management over the last decade or so that are driving SOM changes (e.g., Harrington et al. 1993). Collaborative work is underway to define for rice-wheat systems the biophysical processes at work in SOM changes over time. This research has objectives similar to those of earlier (and highly successful) research on SOM changes in continuous rice systems (see Cassman et al. 1994).

CIMMYT, along with other Consortium members, is committed to helping develop new tillage, crop establishment, rotation, and crop residue management practices that can turn around this problem. CIMMYT researchers in other continents are also actively engaged in research to help improve SOM in major maize or wheat systems — through the Soil Fertility Network in southern Africa (Waddington 1991), for example, and through the Central American Maize Program (Bolaños 1995).

Crop rotations – Suitable crop rotations can go a long way towards fostering sustainability in maize or wheat systems. Here, “rotations” are understood to include crop sequences, intercropping, relay cropping, mixed cropping, and agroforestry systems.

When a cereal crop such as maize is grown over and over again, a build-up of pests, diseases, or weeds can readily occur. In southern Mindanao, for example, maize-maize (and even maize-maize-maize) systems are known to suffer from severe infestations of weeds, especially *Rottboellia* spp. (Harrington et al. 1991). Continuous cereal cropping also may lead to reduced levels of soil fertility. In the Indo-Gangetic Plains of South Asia, CIMMYT-led diagnostic surveys found that continuous rice-wheat systems are inclined to have more problems with soil fertility than systems that feature an occasional legume, pulse, or sugarcane crop (Fujisaka, Harrington, and Hobbs 1994).

Agroecosystems that feature a diversity of species tend to be more resilient, better able to cope with

biotic and abiotic stress, and (relatively) self-regulating (Altieri et al. 1987). This is because diverse systems feature multiple pathways for the flow of energy and nutrients into the system, and because other species often can compensate when one species runs into trouble. Agroecosystem diversity is important, even if diversity is not found in the same field. Farmers in drought-prone areas may grow both maize and sorghum (in different fields), knowing that they can benefit from higher maize productivity and value in relatively good years but relying on sorghum’s greater drought tolerance in relatively bad years.

CIMMYT researchers in collaboration with partners from national agricultural research systems (NARSs) and non-governmental organizations (NGOs) are working in many regions on crop rotation/system diversification strategies to improve system productivity and sustainability. Many of these strategies involve insertion of green manure cover crops or other legumes in maize systems, such as *Mucuna* and *Canavalia* in maize systems in Central America (Bolaños 1995) and southern Mexico (Buckles and Barreto 1996); and groundnuts, pigeon pea, and *Mucuna* in maize systems in southern Africa (Waddington 1997). This collaborative work is not restricted to maize: similar work on diversification of wheat systems is also underway in Bolivia, Bangladesh, and in rice-wheat systems in the Indo-Gangetic Plains.

CIMMYT may be a maize and wheat improvement center — but that does not mean we do not value the contributions of other species in diversified systems.

Soil tillage – New conservation tillage and residue management practices are among the most exciting options available today to improve the productivity and sustainability of maize and wheat systems around the world. And CIMMYT, together with its research partners, is in the forefront of much of this research.

All too often, conventional tillage in rainfed maize and wheat systems leads to a host of problems. The kinetic energy of rainfall on unprotected soil leads to erosion and soil fertility loss and often to a sealing of the soil surface. This sealing process typically results in increased run-off and reduced infiltration of moisture into the soil profile. Two valuable resources — soil and water — are thus wasted (three, if one counts the energy invested in the tillage practices themselves). Excessive tillage also accelerates the process of SOM loss and, in some systems, can badly delay crop establishment, leading to reduced yields, low water and fertilizer use efficiency, and continued pressures towards extensification of farming.

CIMMYT's collaborative research shows that various conservation tillage and residue management practices can ameliorate many of the problems described above. Even a relatively light crop mulch cover has been shown to reduce erosion and crusting, improve water use efficiency, and dramatically improve crop yields, both in maize systems (Scopel 1998) and wheat systems (Wall 1994). In rice-wheat systems in South Asia, zero and reduced tillage practices of various kinds raise yields (through more timely sowing), slash production costs, and boost water and nutrient use efficiency (Hobbs and Morris 1996).

In some instances farmers are immensely enthusiastic about conservation tillage practices, seeing them as a way to transform their cropping systems. This happened in the past with zero tillage practices on hillside maize systems in the Guaymango area of El Salvador (Sain and Barreto 1997), and it appears to be happening now with surface seeding and with zero and reduced tillage practices for establishing wheat after rice in the Indo-Gangetic Plains. However, there are other areas where current versions of conservation tillage practices may be less attractive, their numerous benefits notwithstanding. This often happens when crop residues are important sources of livestock feed (Erenstein 1997).

It must be noted that conservation tillage systems often lead to problems with weeds (Edwards 1987). The usual solution is to use herbicides. All too often, these herbicides are misused with what may be substantial costs to farmer well-being and public health. These costs need to be quantified, and conservation tillage practices developed that rely less on these inputs.

Integrated pest/weed management (IPM/IWM) – Excess pesticide use can be addressed through IPM/IWM programs. This technology is used widely in developed countries and is gaining greater acceptance in the South. Integrated pest and weed management is often cited as one of the pillars of sustainable agriculture because it is based on sound biological principles: a multifaceted approach to pest and weed management usually makes both economic and environmental sense and is less likely to lead to the development of resistance in the target pests.

However, IPM is knowledge-intensive technology, and such technology is often difficult for resource-poor farmers to adopt. There are many “What if?” questions to be answered in adopting IPM successfully, and unless these answers are readily available, at the time when the farmer has to make a decision, losses will occur, or the farmer may place undue emphasis on chemical control. CIMMYT is therefore working to simplify IPM procedures by embodying as much of the IPM technology as possible in varieties with genetic resistances and tolerances. Emphasis on host-plant resistance/tolerance to major diseases, pests, and weeds provides the farmer with a “buffer” in his or her IPM program, through the adoption of a much simpler technology: a new variety.

Some of the successes of this approach have already been described in the section on genotype. However, even in the most successful cases of host-plant resistance, such as durable leaf rust resistance in wheat, it is essential to combine resistance with other IPM strategies. For example, CIMMYT seeks to integrate its work on pedigree diversity in wheat with other work on varietal diversity and system diversity in farmers' fields. Simply put, we seek to have many genetically broad-based varieties grown in farming systems that are diversified with other crops and enterprises. This, of course, means partnerships with others who work on the various facets of the system.

Whilst much has been written on crop varieties with good resistance to pests and diseases, less is known about varietal tolerance to weeds, which remains a poorly exploited

component of IPM (or IWM, to be more specific). However, as shown in Figure 4 (p. 7), CIMMYT varieties through their enhanced efficiency are more effective in tolerating weeds than old varieties. However, if one actually selects for weed tolerance some spectacular results have been obtained. For example, Reeves et al. (1993) showed that at a similar level of weed infestation the most competitive wheat cultivars had no yield loss from weeds, whereas the least competitive lines had yield losses of 20-40%. Given the development of weeds (e.g., *Phalaris minor*) resistant to herbicides in the rice-wheat systems of the Indo-Gangetic Plains (Malik et al. 1995) and elsewhere (Mexico, for example; see Sayre 1998), there is an urgent need for more support to develop competitive cultivars in all crop species.

Last, but by no means least, the complexity of IPM/IWM systems means that they are not easy to manage at "arm's length." For resource-poor farmers with limited or no access to remote communication centers, a "hands-on," community-centered approach is essential to provide timely and appropriate advice. Often NGOs are the most appropriate agencies to adapt and deliver such advice, and this is another clear example of the need for partnerships between those who develop, and those who deliver and adopt, sustainable agricultural systems.

The Role of People (P)

It is people who must implement and adopt sustainable agriculture, and it is people who CIMMYT and others seek to help. It is therefore somewhat

strange that the role of people in developing, refining, and implementing sustainable agricultural technologies has often been overlooked. Many of the formal priority setting systems for sustainable research have not tapped the knowledge of farmers, or at best have done so only late in the process when farmers are often asked to adopt some technology that they may not consider very appropriate for their needs. If sustainability is to be a reality, far greater emphasis must be given to an effective combination of farmers' traditional knowledge with the contributions of science.

There may be significant cultural and social issues to consider when accessing information from farmers, but none are insurmountable. Farmers the world over are generally conservative, risk-averse individuals who are most comfortable in their own environment. For this reason, it is essential that farmers' contributions are solicited in a way that addresses their needs, values, and objectives. People's sense of "ownership" of new technology is critical if we are to progress rapidly from research to adoption and impact. Just as sustainable agriculture requires a new research paradigm, it also requires a new paradigm for involving people — the research-adoption continuum (Reeves 1987).

In this continuum, which is depicted in Figure 5, all key partners have a role in the process from priority setting to adoption. Of course the contributions of groups throughout the continuum vary (represented by bold letters in the figure) as the emphasis switches from research to extension to adoption. It is important to note however that all

partners are involved in priority setting, planning, and deciding what should be done. If you wish to know what farmers need, why not talk to them? They can often be instrumental in finding an appropriate way forward.

One example of farmer participation in research is a collaborative project between CIMMYT and Mexico's Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). The project, which focuses on small-scale farmers in the Central Valleys of Oaxaca, seeks to assess whether collaborative breeding by farmers and researchers can increase farmers' welfare while maintaining or enhancing genetic diversity.

Throughout this region we have collected 152 maize samples that are representative of the variation in local maize landraces. The farmers who donated these landraces were interviewed about their perceptions of the positive and negative traits of the landraces, as well as their uses. The positive characteristics cited most frequently were associated with consumption, such as taste and suitability for special preparations. Other valued characteristics included good yield and short duration in the field. The negative traits cited most

Priority setting	REIF
Planning	REIF
Research	REIF
Validation	REIF
Demonstration	REIF
Extension	REIF
Adoption	REIF

Figure 5. The research-adoption continuum. R = research, E = extension, I = industry, and F = farmers.

frequently were related to low yield and poor storage. The farmers identified 11 uses for their maize, including eight special preparations. The importance of consumption characteristics and the high number of uses suggests that home consumption of maize is an important concern for these farmers, and highlights the cultural importance of maize in the region.

Trials were established with the 152 samples, 17 historical accessions from the CIMMYT and INIFAP germplasm banks, and one improved population of the local landrace, for a total of 170 maize populations. Agronomic measurements were recorded for each population. Farmers from the region were invited to evaluate the 170 populations at physiological maturity and harvest. At harvest, 216 farmers (117 women and 99 men) came to evaluate the materials. The farmers' choices and the agronomic data have been combined, and the maize samples that were of most interest to the farmers were identified. Some samples were chosen more frequently by females, and others by males, whereas a few samples were important to both groups of farmers. These populations will be the basis for future breeding efforts.

An interesting outcome of this work is that the maize population chosen most frequently by women farmers yielded the least under trial conditions. This finding emphasizes the importance that women place on criteria other than yield. We are currently investigating the specific criteria used by men and women and relating these criteria to their specific socioeconomic and cultural

characteristics. These results are still preliminary, and future research will be modified based on what we learn in the process, but it is already clear that farmers' role in this research is invaluable.

In many NARs, both North and South, the lack of effective communication with farmers is still a major weakness. To make matters worse, investment in formal, government extension services has declined even more sharply than the investment in research. As disturbing as this trend may be, it has opened new opportunities in some parts of the world for systems that are proving to be particularly effective. The defining trait of these new successes is that they are "farmer-driven." For example, more than 40% of Australia's farmers belong to the LandCare movement. The movement comprises community-based farmer groups who identify their own issues and priorities and then seek appropriate assistance from researchers, industry, and other farmers in identifying and implementing solutions. Increasingly, funding support is moving from government extension services to these dynamic farmer groups. Whilst examples from the North are not always appropriate to the South (and vice-versa), farmers' control of their own destinies in relation to technology adoption is fundamental to further progress.

Many other examples of such an approach can be cited, but the general principle for the adoption of the new GxExMxP paradigm is involvement of partners throughout the research-adoption continuum. *People and Partnerships*, the title of CIMMYT's new Medium Term Plan, describes our focus on the people we seek to

help and the partnerships necessary to do so. Sustainable agriculture will not be a reality unless people from all parts of this continuum collaborate effectively to reach their common goal.

Bringing It Together

In working along the research continuum towards farmers' adoption of sustainable systems, three challenges present themselves. First, a range of technologies must be integrated at the farm level. This process is far more complex than promoting a single change in management in a farming system. Second, given the enormous size of the task — literally every farmer's field in the world — there must be an effective and efficient way to "scale up" from individual research sites. This issue is particularly important for CGIAR Centers working ecoregionally. Given these complexities, the third challenge is to develop and disseminate the information that all partners require to contribute effectively to sustainable farming systems.

Fortunately the tools of modern science show significant potential to meet these challenges. Computer simulation models of crop and soil processes, GIS, and user-friendly information systems are key elements of the research process for sustainable intensification of agriculture. Aside from contributing to the development of risk management strategies at both the farm and national levels, these tools are also the most effective means of extrapolating information in time and space — that is, in addressing the issue of how to "scale up." To carry out the GxExMxP paradigm as effectively as possible, CIMMYT has recruited people with the skills to use and further develop these tools.

One example of the further development of tools for sustainable agriculture is the Sustainable Farming Systems Database (SFSD) currently being produced at CIMMYT. This database should vastly improve the collection, storage, and distribution of research information that is relevant to efforts to improve the sustainability of wheat- and maize-based farming systems. The SFSD is a flexible information system that brings together results on farming systems research, scaled from the experiment level to the farm level and the regional level. Data types include experimental results, surveys, expert opinions, results of on-farm monitoring, census data, and scouting reports. Any data source can be georeferenced and linked to information on researchers, institutions, and associated bibliographic material. The SFSD permits flexible queries about locations; single crops or rotations; tillage and harvest practices; use of labor, machinery, and chemicals; and system performance. Data can be extracted for use in other applications such as spread sheets, statistical packages, crop simulation models, and GIS. Available on CD-ROM and through the Internet, the SFSD will facilitate a global interchange of research experience related to cropping systems and their impact on the environment.

Information technology is therefore crucial to sustainability, and CIMMYT is committed to making information available in the most accessible and efficient form for its partners. This technology has a vast

and still underexploited potential to greatly increase research efficiency by linking information across disciplines and geographical locations.

Another example of the power of new information tools is our International Wheat Information System (IWIS), available in CD-ROM.³ Local naming conventions for wheats once precluded efficient communication among researchers, but by identifying germplasm unambiguously, IWIS removed the barriers to the association of different kinds of information on wheat. Marrying the management of performance data with the principle of unique identifiers has provided unanticipated querying power and enabled multidisciplinary data integration. Through the IWIS CD (which features family trees for more than 1.7 million genotypes and performance data from 77 countries), information from diverse sources is integrated, linked to sources of seed, and put to work in wheat improvement. Major new insights into adaptation are being gained through feedback between genetics — conventional and molecular — and environmental information. Displaying genetic information on the branches of family trees of individual wheats facilitates genetic inferences, helps plan strategic crosses, and reduces laboratory testing. For example, when the database shows that the direct parents of a cross do not differ for an important gene, the gene can be inferred in the progeny, thereby saving the cost of direct testing. Other major savings and benefits to date

include quantifying the genetic diversity in farmers' fields, tracking seed stocks so they may be replaced after civil crises, eliminating repeated introductions of wheats to collaborators (and the associated quarantine costs), and global sharing of information on genes for bread making quality. Now that the IWIS CD has been distributed to 78 countries, CIMMYT is committed to providing write-access to IWIS for researchers in developing countries. This will result in a highly streamlined, multi-directional information flow and full participation of partners in NARSs.

Achieving Impacts

We know that the sustainable intensification of agriculture in farmers' fields is not merely a desirable achievement but an essential one. With 200 people added each minute to our global population, and with all of us dependent on a shrinking agricultural land base, sustainable intensification is the only practical and appropriate choice for the foreseeable future.

The time for talking is over, and the time for concerted action is here. To act — to truly address the GxExMxP paradigm — we need strategic partnerships, and as partners, we must bring to the table all the available and appropriate technologies. Let us not argue about whether a given technology will work; instead, let us focus on how we as a team can make it work, and work well.

Biotechnology is a key tool that must be brought to bear on the traits that save lives — apomixis, drought tolerance, and resistance to pests and

³ The latest edition has been distributed to more than 1,000 partners around the world.

diseases. In the debate over the applications of biotechnology we have been distracted for too long by flavorsome tomatoes, "designer" chocolates, and potatoes that do not turn brown when cut early for dinner. This is biotechnology for the well-off, who quite rightly can choose whether to take it or leave it! The resource-poor have no such luxury. They need drought-tolerant maize now.

As I have emphasized here, "business as usual" will not achieve sustainable intensification of agriculture in farmers' fields. We must plan and respond to change, for sustainability is a moving target. CIMMYT has changed to build on its strengths in G, through greater in-house emphasis on ExMxP, and with a view to building strong alliances with partners who have strategic strengths in these areas – be they NARSs, ARIs, NGOs, the private sector, or other Centers. Together we can prevail, and prevail we must.

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Economic Policy for Grain Production in Kazakhstan

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How to increase grain production is the main problem of agriculture in Kazakhstan. Wheat is the most important crop grown in the world. Its share of total global production is 30%. Thanks to the biological and climatic potential of Kazakhstan's agricultural areas and the yield potential of our cultivars, we are able to produce enough wheat to satisfy the needs of the population and still export the larger part of it. At the beginning of 1997, the agricultural area comprised 220.4 mln ha. This includes 29.1 mln ha of arable land, of which 1.7 mln ha are irrigated.

Based on soil, climatic, and economic conditions, Kazakhstan may be subdivided into five major regions: Northern, Central, Western, Eastern, and Southern. Seventy-one percent of the wheat area is in the Northern region, 10% is in the Western part, 5% is in the East, and the Central and Southern parts each account for 7%.

In analyzing Kazakhstan's grain production system, several periods of history can be singled out. The first period was before the development of virgin lands (1946-1953). The area sown to cereals was only 7 mln ha, the average yield was 0.56 t/ha, and total production was 3.9 mln t.

During the second period (1954-1960), virgin lands—25 mln ha of new land—were brought under

cultivation. The area sown to cereals increased to 24.6 mln ha, the average yield rose to 0.7 t/ha, and total production was 17.2 mln t. The extensive land use during this period was practiced at the expense of soil fertility.

The third period (1961-1984) was characterized by the vast development and extension of soil conservation methods, which helped to stop wind erosion, preserve soil fertility, and raise wheat yield levels. In the fourth period (1985-1990), intensive grain production methods were introduced. The well planned intensification of soil conservation practices during this period raised the average yield to 1.08 t/ha and total cereal production to 24 mln t per year.

As a result of an active grain production policy, the area sown to cereals and grain legumes reached 22.7 mln ha, including 13.5 mln ha of wheat. This represented 2.9 and 13.5% of world area under these crops, respectively. Judging by cereal production, Kazakhstan became equal to Canada and in wheat production closely approached it. Wheat's share of Kazakhstan's cereal production reached 60%. During this time, average cereal production reached 20 mln t, of which 51% was wheat; this made it possible to meet the demands of the population and export 5-6 mln t of bread and durum wheat.

During the fifth period (1991-1997) Kazakhstan has undergone the transition to a market economy. This period has been characterized by a deep economic and agricultural crisis. No scientific research was conducted, and this negatively affected cereal production technology. Crop rotation is not practiced and the seed production system is not operating. Primitive technology is used to till fallow fields. Soil tillage in the fall is done on one third of the area. Fertilizers are not applied. There is minimal weed and disease control and, as a result, the number of weeds in the fields has increased. Yields and total production are decreasing. Compared to 1991, the year before the reforms started, in 1996 the area under cereals dropped by 7.2 mln ha and that under wheat by 2.1 mln ha. It should be emphasized that the rate of wheat area reduction is 3.7 times lower than that of all other cereals. Since wheat is more competitive on the market, producers are inclined to maintain its area. As a result, 73.5% of the area sown to cereals is currently planted to wheat.

To complete this brief historic review, I should point out that until now agricultural policy in Kazakhstan has been oriented towards expanding the area under cereals in general and wheat in particular. This has had some negative consequences. The sandy soils of Akmola, Aktubinsk, Pavlodar, and other regions suffered

from extensive tillage. The sandy chestnut and grey-brown soils of the desert-steppes with low yield potential were brought into cultivation with adverse effects on the ecology and economy.

The factor limiting the expansion of grain production is the poor state of agriculture in the Republic as a whole, currently under extreme conditions. Almost 80% of arable land is in regions with 220-350 mm of rainfall per year. There is also great variation in the amount of precipitation from year to year, ranging from very dry to medium dry and favorable conditions. There was a serious threat of drought in 11 (38%) of the last 40 years. The average yield in those years was 0.3-0.7 t/ha, and average grain production was 12.4 mln t per year. There were 17 (42%) medium dry years, with average yields of 0.73-1.03 tons per hectare. Only 12 years (30%) were there favorable conditions for grain production when the yields fluctuated from 1.05 to 1.48 t/ha. Average grain production in those years was 31 mln t. Although we cannot avoid the unfavorable climatic effects on yield, we can temper their negative influence. This has always been done and will be done by agricultural researchers.

Kazakhstan, being among the world powers, must have sustainable grain production. Sustainable grain production means first of all food security, high prestige of the country in the world community. Essential economic, scientific, and technical prerequisites must be met if we are to achieve this goal. Plant resources that use solar energy, moisture, and soils are renewable. Mineral resources are not. That is why in the strategic plans

for national development we should first of all count on agriculture, not only on oil, gas, and minerals.

To successfully increase wheat production, first of all it is necessary to restore Kazakhstan's lost production potential, raise annual production based on intensive technologies, and improve grain quality. The targeted objectives are to stabilize the cultivated areas at 12-13 mln ha, increase average yield to 1.2-1.4 t/ha, and increase total production to 14-18 mln t. This would fulfill the domestic food requirements and raise our export potential to 10-14 mln t. Market capacity will allow us to sell this amount of wheat at a profit.

Our export market is, first of all, the CIS states. Russia can buy 3-4 mln tons, Uzbekistan up to 5 mln tons, Turkmenistan and Tadjikistan 1 mln tons each, Kyrgyzstan and the Caucasian states 0.5-0.6 mln tons, and Belarus up to 2 mln tons. Our market is expanding to other countries such as China, Iran, and Pakistan. Besides wheat, we can sell rice, oats, and groat crops. The cost of transporting grain from the US or Canada to the CIS countries is twice as high as that of transporting grain from Kazakhstan.

These goals can only be achieved if radical changes are made in structural, technological, technical, breeding, investment, and market grain policies. We should consider the socioeconomic changes that have taken place in rural areas since 1991. First, huge state farms and collective farms were replaced by private farms: peasant holdings, agricultural production cooperatives, associations, and joint-stock companies. They completely changed

the size and limits of land use, and the agricultural system. Second, the centralized planning system that specified all the indices of activity from top to bottom has completely disappeared. Real agribusiness came to life, and its success completely depends on the initiative, zeal, and knowledge of rural producers. In a nutshell, a new era has come to the village, the post-privatization era. Agricultural science should be based on this premise. We will not start from scratch, of course. Our present agricultural researchers have received a rich heritage from the previous generations of researchers.

The research institutions of the Republic have developed four principal types of farming: 1) the soil conservation farming system on rainfed lands cultivating spring cereals in the northern, central, and eastern regions; 2) the soil conservation system on rainfed lands growing winter and spring cereals and forage crops in the south-east; 3) the system of mountain agriculture on rainfed lands with cereal and forage crops in the eastern and southern regions, and 4) the irrigated system with cultivation of industrial and forage crops, vegetables, and cereals. In their latest work on regional farming systems, researchers consider with a greater degree of differentiation the specific features of climate, soils, weeds, pests, and diseases, as well as the presence of plant nutrition elements.

Modern regional farming systems must fulfill four main needs: provide high stable yields, preserve and increase soil fertility, increase labor productivity and profitability of agricultural business, and protect the environment. While developing

ecologically balanced, intensive technologies for cereal cultivation, scientists have undertaken research aimed at developing the main aspects of regional farming systems. An optimal structure of sown areas and crop rotation was developed, and the area under major crops was specified for every region. Soil and climatic conditions and the tendencies in each area were considered in developing agricultural holdings. The tillage system is being improved making the most efficient use of natural resources and moisture and, at the same time, protecting the soil from water and wind erosion. In regions where there is not enough moisture, wheat-fallow rotation is recommended with subsoiling for more effective use of winter precipitation. The effectiveness of soil protective systems compared to the regular tillage system is being studied taking into account the reduction of energy and labor inputs, protection of soils against erosion, and increased grain yield.

In the Northern region of the country, the A.I. Baraev Kazak Institute of Cereal Production, together with state agricultural research institutions, provides scientific support for the development of regional farming systems. The V.R. Viliams Kazak Agricultural Research Institute, in cooperation with state regional and plant breeding stations, carry out this work in the other four regions of the country. Regional agricultural research institutes work in close cooperation with the two above mentioned coordinating institutions. Cereals are the core of their research work.

These research institutes and experiment stations recommended the following agronomic activities to stabilize and increase the wheat production in Kazakhstan.

1. Sowing the crop in favorable zones and microzones with the most fertile soils.
2. Introducing science-based crop rotations which will provide yield increases of 0.12-1.14 t/ha on irrigated lands and 0.25-0.4 t/ha on rainfed lands. In modern agriculture it is necessary to use flexible patterns of crop rotations which will be applied on the basis of economic considerations and farm needs, market demands, and soil fertility. Such crop rotations should provide the maximum wheat output and the highest net profit per hectare. Unfortunately, neither science nor production are ready to implement such crop rotations.
3. Changing the proportion of area devoted to cereals and fallow considering weather conditions. In spring, when the supply of soil moisture is 80-90 mm and more per meter of soil profile, spring crops should increase and fallow should decrease. In autumn when there is no moisture in the soil or in spring when moisture supply is less than 50 mm, spring crops should be reduced to the minimum and 30-40% of the area should be left under fallow. The increase in area under fallow in dry years will result in higher grain production the next year.
4. Using combined tillage in rainfed areas. Plowing is allowed in fields with perennial grasses and in very weedy fields; on all other fields, a chisel subsoiler should be used.

5. Applying the optimal cereal cropping technologies in different agro landscapes based on the theoretical and applied research conducted by the A.I. Baraev Kazak Institute of Cereal Production and the V.R. Viliams Kazak Agricultural Research Institute.
6. Applying intensive technologies using the necessary amount of mineral fertilizers, seed treatment, and plant protection measures.

We should sincerely say that agricultural scientists are not ready to give valuable practical recommendations and to respond to all these tendencies under the new market economy. This especially refers to small peasant holdings, the number of which has reached 60,000, with an average farm size of a little over 50 ha. We do not know how to address the issue of technology and crop rotation for these small farms.

The seed production system needs to be completely rebuilt under the new economic conditions. Research and practical experience show that wheat yield increase up to 30% depends on the variety and high quality seeds. During the time of reforms, seed producers failed to maintain the seed production system or to adjust it to the new conditions. The seed production system was destroyed. Fortunately, the seed production structure represented by research institutes and state experiment farms and stations was preserved. That means that we have basic and elite seed production. Based on this, we must resurrect the overall seed production system.

A specialized network of seed production farms existed in the country for many years. The farms were located in different

agroecological zones. There was also a system of extra payments for varieties, which stimulated the interest of seed producing farms and seed producers. Special actions were undertaken to supply elite and other seed production farms with labor, cleaning machines, warehouses, and other buildings.

All this should be resurrected on a new economic basis. Private farms should participate in seed production. The Eastern Kazakstan Institute has already contracted them. Together with the regional agricultural administration, it defined a network of farms and joint stock companies that will produce seed. But this program will only work if it is supported by a well organized seed market. However, here we also work in the old way hoping that somebody will buy the seeds. But it does not happen this way anymore.

The associations "Assail Tokum" in the South and "Elite Seeds" in the North were established by the national coordinating and regional institutes to initiate a new seed production system.

Plant breeding is of prime importance for wheat production. Seventy varieties were released in Kazakstan including 32 (46%) locally developed ones. In breeding institutions about two million entries are screened annually and 3200 lines are yield tested for selection of potential varieties. Many of them were developed using the achievements of different biological sciences such as biotechnology, biochemistry, genetics, cytology, and physiology. Released cereal varieties have highly valuable biological and commercial characteristics. At present, varieties bred in Kazakstan occupy more than 25% of the wheat area and they may

expand. Among them early maturing spring wheat Kazakstanskaya rannspelaya is becoming more and more popular. It has a yield potential of 5 t/ha, which is 0.4 t/ha higher than the well known check Saratovskaya 29, which was grown in the Republic for a long time. The important characteristic of this variety is its early maturity, its disease resistance, tolerance to lodging, drought, and shattering, and its high grain quality. The variety has been released and is successfully cultivated in Kokshetau, Kostanay, Northern Kazakstan regions. Varieties Tselinnaya 24, Eritrospermum 35, Shortandinskaya 125, Tselinnaya 3C, and Karagandinskaya 70, released in the Northern and Central regions, also have high yield.

An important factor that increases breeding efficiency is genetic resources. The more diversity there is, the higher the chances of quickly developing varieties and hybrids that meet production requirements. With this in mind, breeding institutions have taken the steps necessary to create, store, and use plant genetic resources, and international germplasm exchange has been organized. Despite certain breeding successes, producers complain because, up to now, varieties bred in Kazakstan have not occupied the leading position in the country.

Mechanization policy is very important for wheat production. However, in recent years the number of equipment and machinery used has been decreasing sharply. Because of the price disparity between industrial and agricultural products, the demand of rural producers dropped so much that farm

machinery and tractors are practically not renovated, and plants that manufacture agricultural machinery have stopped. More than 70% of tractors and agricultural machinery have outlived their useful life and should be discarded. The aging of machinery has resulted in reduced quality of work and in the underproduction of agricultural products.

It is estimated that the machinery available in the Republic allows planting and harvesting cereals on optimal agronomic dates in an area not exceeding 12 mln ha, and this area will annually decrease. To renovate the machinery produced in the CIS countries, investments of \$500-550 per hectare are needed. If machines are imported, the cost will be even higher. For the 17 mln ha under cereals, an investment of one billion dollars is required to renovate the machines annually.

Our researchers, together with experts from the Ministry of Agriculture, have proposed developing technologies for cultivating and harvesting cereals, and also using foreign made machines. They specify which machinery should be bought in which country, which should be assembled in the Republic, and which should be tested.

The following tractors are recommended for use:

- Class 5 T – wheel tractors (K-701 M, K-744) and caterpillar of Caterpillar (USA) type or T-250 (Russia);
- Class 3 T – caterpillar for general use (DT-145C, BT-100. BT-200 Russia), Pavlodar tractor DT-75T;
- Class 1.4 T – wheel tractors MT3 (Belarus) and others.

To meet future machinery requirements, joint ventures with foreign companies should be organized to produce class 5 T caterpillar tractors and class 2 T wheel tractors with a 120-140 horsepower engine. These tractors are recommended for harrowing and sowing. Some imported machines may be widely used in the Republic - the "Flexy Coil" sowing system (Canada) that performs five operations (tillage, sowing, fallow tilling, fertilizer application, fall plowing). It is necessary to organize manufacturing of this machine by domestic manufacturers (Tsellinselmash, Kazakhselmash) together with the company Flexy Coil. It is also necessary to accelerate the manufacture of similar machines developed in the Republic: SPU-8 and SPU-12.

Cereals should be harvested using combines with a harvesting capacity of 8-9 kg/sec (combine harvesters "Don-1500" Russia, "Dominador-98-108" of "Klass" Germany, John Deere, USA, and others) which make up 60% of all the combine harvesters in the country. The remaining 40% can have a capacity of 5-6 kg/sec (type SK-5M Niva, "Enisey-1200" and E-514). To ensure their efficient use, it is necessary to organize the manufacturing of reapers with wide gripper of the ZHKHM-9, ZHKH-11 types. Issues relating to jointly producing combine harvesters in the Republic with leading foreign companies should be addressed.

As for grain processing, reconstruction of cleaning facilities is necessary and replacement of the grain cleaning machines ZAV-40 (100) and KZS-50 with technologies using pneumatic inertial separators designed by NPO TSKHM and grain dryers "Tsellinnaya-40" designed by the A.I. Baraev Kazak Institute of Cereal Production. Under current economic conditions, the state should set priorities for the utilization of machinery and equipment in agricultural industrial complex. If this is not done, mechanization and, consequently, production will decrease sharply.

The following possible ways of the state support are suggested:

- to give producers of consumer goods special long-term loans for purchasing equipment;
- to increase leasing fund in the national budget to provide producers with imported and domestic farm equipment;
- to stimulate by economic means the industrial and maintenance enterprises producing spare parts and accessories for tractors and farm machines;
- to find the means for implementing the first stage of the agricultural production development program.

I want to emphasize the development of new machinery by Kazakstan specialists as a special issue. This question is especially important because to obtain the design documentation is incredibly expensive. The design potential that we used to have in the Republic has weakened because of lack of funding.

The problems that Kazakstan agriculture is facing have diminished export opportunities. Only grain is still exported on a permanent basis. Every year we export from 6 (1992) to 2.5 mln t (1995). However, with the reduction of grain exports, flour exports are growing. Our main export is still wheat, but the situation has changed lately. Wheat grain quality has deteriorated due to faulty agronomic practices. Now we produce mainly wheat of 3rd or 4th grade quality with less protein and gluten.

The establishment of the grain market requires new organizational and technological solutions to problems of grain production, storage, processing, and trade. A grain storage network should be established in the agricultural industrial complex to provide maximum effectiveness in grain transportation, treatment, storage, and processing. However, the development of grain processing facilities should not depend on the producer's financial resources. It should be coordinated in the whole region. That is why it would be better to organize highly productive enterprises that would take grain and dry, process, and store it. They may also include small flour mills and combined fodder shops using waste-free technologies. Flour mills with a production capacity of up to one ton per hour should be established. The flour should be first class.

A conceptual program for the development of an agricultural industrial complex in Kazakhstan up to the year 2000 was big contribution to the strategy of sustainable grain production. It was presented by Kazakhstan Academy of Sciences researchers in 1993 and approved by the government. The program effectively allocates and structures farming areas and the main crops in the different regions of the country considering biological and climatic potential as well as ecology. A step by step reduction of cultivated area is planned by excluding the less fertile soils from the farming area and concentrating production on the best lands within 20-25 mln t including 14-18 mln t of wheat. Three main

factors of intensification were planned: mineral fertilizer application, release of new varieties, and application of cereal production technologies that protect soil and water resources.

Only the first part of this program, the restructuring of farming areas, has been implemented to date. However, in many cases it was not done on a scientific basis, and even highly productive lands are not being sown in many regions. The second part of this program providing for production intensification is not being implemented.

This program was developed during the first stage of the transition to a market economy. Now it should be corrected considering the existing post privatization status of agriculture. This conference will contribute to fine-tuning the program, and attention should be concentrated on the major problems of wheat production in Kazakhstan.

Table 1. Cereal production statistics in Kazakhstan.

Year	Total grain production (mln t)	Wheat production (mln t)
1949-1953	4.33	3.00
1954-1960	15.66	12.33
1961-1965	14.00	10.66
1966-1970	20.79	15.84
1971-1975	20.31	13.65
1976-1980	27.31	17.00
1981-1985	20.00	12.00
1986-1990	23.98	13.32
1991-1995	17.32	10.65
1996	11.65	7.33
1997	13.00	n.a.

Scientific Support for Spring Wheat Production in Kazakhstan

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Farming in Kazakhstan is relatively young and has a 230-year history. In 1764 Abylay Khan asked Katherine II to send ten Russian peasants to teach the Kazak people how to farm and fish. The Russian Ministry of Foreign Affairs satisfied the request and in addition asked the Khan to send ten Kazaks to Russia to learn how to farm and later on supplied them with agricultural equipment. Meanwhile Russian peasants settled in the Zerendy and Shortandy areas. We should keep this fact in mind when speaking of the Kazak (former All Union) Research Institute of Cereal Production named after A.I. Baraev, its founder and first director.

The soil protective farming system developed by Institute staff under the leadership of Academician A.I. Baraev in the late 1960s made it possible to control wind erosion and increase crop yields due to: a) appropriate utilization of winter precipitation using sub-surface cultivation and snow plowing, and b) better utilization of summer rainfall due to optimum planting time and application of phosphorous fertilizers.

The theoretical basis of the intensive technology for spring wheat production in Kazakhstan developed by scientists at the Institute under the leadership of

Academician M. Souleimenov made it possible to increase efficiency of wheat production while preserving the soil and natural resources. The average grain production in 1986-1990 in Kazakhstan was 24.1 mln t. Thus, the average amount of grain per capita was 1.5 t and in Northern Kazakhstan 3.5 t per capita. Some 58-65% of the grain produced was of marketable quality, compared to the average 40% in the former USSR. Until very recently the farming system in Northern Kazakhstan was aimed at maximum grain production using the vast land resources.

If we compare the average annual grain production during the last three years to the previous five year period, production decreased by 48% and is now only 11.8 mln t. The dry climate of Northern Kazakhstan affects the quality of wheat. It contains 15.4-18.0% protein, has high gluten strength (420-800 alveograph units) and the overall quality is superior to that of grain produced in the European and Eastern parts of Russia. In fact Northern Kazakhstan is the major producer of superior quality wheat, which is highly valued by the baking industry. This grain is used to improve the flour from the wheat produced in the European part of Russia, Ukraine, Belarus, Latvia, and Estonia.

Currently the main areas under spring wheat cultivation in the Republic are located in the North. In 1996, 74% of all wheat in the Republic was grown in six regions of Northern Kazakhstan: Akmola, Kostanay, Pavlodar, Northern Kazakhstan, Kokchetav, and Torgay. It is grown on gray forest soils, leached, common and southern chernozem, dark chestnut and chestnut soils that occupy 8.3, 17.1, 28.2 and 41.7%, respectively, of the arable land in Northern Kazakhstan. The humus content in the 0-20 cm layer varies from 3-4% (chestnut soils) to 6-9% (common chernozem). These soils are characterized by potentially high content of nitrogen, phosphorus, sodium, and calcium. The fertility potential of these soils is high.

Under the conditions of Northern Kazakhstan, the most significant climatic factor that determines yield is precipitation, which varies from 250 to 450 mm. The deep penetration of moisture into the soil (up to 1-1.5 m) is possible in spring due to snow in winter (60-120 mm). Summer precipitation is about 130-200 mm annually. Very often a small change in the time of summer rainfall results in significant change in spring wheat yields. For this reason the appropriate sowing date is of paramount importance. There were

¹ A scientist, breeder, biotechnologist, and expert in genetic resources, Professor Onal S. Shegebaev passed away in November, 1997.

years when sowing date was the major factor influencing yield and quality of wheat – more important than soil tillage methods, application of fertilizers and herbicides, preceding crop, and variety.

At present, the transformation of agriculture and its transition to a market economy put forward new objectives for agricultural science. It is important to develop technologies that need fewer resources. For agricultural enterprises having different supplies of agricultural machinery and situated in different climatic zones there should be a wide choice of technologies, crop rotations, and varieties.

The common landscape of Northern Kazakhstan is a flatland which covers 80% of the territory. Some very long slopes up to 0.5° stretch for 18-20 km. These slopes are important for wind and water erosion. Within each farm it is necessary to identify different categories of soils based on their fertility, ecological condition, and productivity (Table 1).

The 1st category – arable land for the production of ecologically clear grain. This land is most fertile, less prone to erosion, and constitutes about 30% of the whole area. With the lack of fertilizers, weed control, moisture, and nutrient accumulation is done in the fallow field. The fertility

of such land should be maintained by conserving crop residues in the field and introducing green manure crops and perennial grasses at the end of rotation, i.e. exclusively through biological methods. The residual moisture in such soils is about 160 mm without snow plowing, which significantly reduces fuel consumption. The yield level on this soil is 1.8-2.5 t/ha.

The 2nd category (33%) - land is for production of high quality grain for export. This soil is fertile with very little erosion and salinity. The application of chemicals allows maintaining profitable production with a yield level of 1.2-1.8 t/ha.

The 3rd category (23%) - land is suitable for production of forage grain and perennial grasses for forage. These soils are subjected to erosion, which requires fallowing to occupy some 20-25%. The yield level is 0.8-1.2 t/ha. Wheat production technology here would be low input.

The 4th category (14%) - land is least fertile and most subjected to erosion. It is better to take this land out of grain production and use it for perennial grasses. If necessary cereals can be grown using soil protecting technologies with wheat following fallow and the other fields occupied by forage crops.

The utilization of land as described above would make it possible to increase profitability of grain production by applying intensive technologies on more fertile soils. On the other hand, this rational use of land allows correcting mistakes made at the very beginning of the development of virgin lands.

In the process of developing a soil-protective farming system and intensive wheat production technologies, the crop rotation has been changed greatly. The 3- and 4-field rotations gradually evolved into 6- and 7-field rotations as the availability of machinery improved. New, more complex crop rotations were developed in which fallowing was substituted by oats, maize, or annual grasses. Crop diversification and the creation of heterogenic landscape best met the requirements of normally functioning ecosystems. Unfortunately, these recommendations cannot be deployed by farmers as widely as they should due to known difficulties in the supply mechanism.

At present scientists recommend 3- and 6-field rotations depending on the type of farm. When there is a lack of intensification means, the use of fallow is the basis of stable crop production. The situation in the grain market requires crop rotations with 25% fallow. Its increase up to 33-50% will result in the fast development of erosion processes and decrease in soil fertility (Table 2). Such crop rotations have less organic residues incorporated into the soil than are necessary to compensate for the mineralization process.

Table 1. Classification of land based on conditions for spring wheat cultivation in Southern calcareous chernozem.

Land category	% of area	Humus content	Snow depth	Relief degree	Water erosion	Yield (t/ha)	Production conditions
I	30	>4.5	>41	<0.2	None	1.6-2.0	Good
II	33	4.0-4.5	31-40	0.2-0.5	Medium	1.2-1.6	Medium
III	23	3.0-4.0	21-30	0.5-1.0	Weak	0.8-1.2	Poor
IV	14	<3.0	<20	>1.0	Strong	<0.8	Very poor

We should emphasize that black fallowing is not very good for grain producers but rather an enforced measure to control weeds in summer. There are circumstances when fallow fields are exposed to strong winds and fast snow melt becomes a real test site for wind and water erosion, which causes losses of up to 140 t of soil per ha (or 0.7% of humus). Decades are needed to restore this soil. It is worth mentioning that only with the timely and precise implementation of all components of fallow management is it possible to increase spring wheat yields by 2.5-3 times. For instance the yield of spring wheat was:

- a) after zero tillage (2-3 cultivations): 0.87 t/ha
- b) regular technology (4 cultivations and P80 applied in fallow): 1.64 t/ha
- c) intensive technologies: 2.29 t/ha

The most important element of the soil protection system is the use of chisel subsoiling. Unlike ordinary plowing, it controls erosion and accumulates moisture in the soil. However, plowing is efficient for the control of septoria and Hessian fly. In some areas that are free of wind erosion, plowing is an effective means of pest control.

Table 2. Humus content (%) in the 0-20 cm soil layer in different fallow-cereals rotation systems on Southern calcareous chernozem.

Crop rotation	At initiation - 27 years ago	Losses since initiation	
		%	ton/year
Permanent fallow	3.40	12.8	0.40
2-field*	3.51	10.0	0.31
3-field	3.48	10.8	0.33
4-field	3.91	-	-
5-field	3.82	2.0	0.06
6-field	3.78	3.1	0.10

One very important problem of spring wheat production is the production costs:output value ratio. Our calculations show that the cost of growing wheat as the 2nd-6th crop after fallow would be US\$ 166.5/ha, provided the farmer has full supply of fuel and chemicals. To break even the farmer has to harvest yields of 1.38 t/ha (Table 3). If he uses only 33% of the chemicals and fuel required, costs drop to US\$ 103.2/ha, and if he uses no chemicals, to US\$ 71.1/ha. The wheat yield needed to break even would be 0.86 and 0.59 t/ha. Thus, taking into account the current prices of industrial products versus grain prices, intensive farming is only profitable if yield exceeds 1.4 t/ha. For expanded production with 25% profitability, yield should be 1.72 t/ha. At present farmers practically do not apply fertilizers and crop protection chemicals. The average production costs for wheat ranges from US\$ 75.9 to 108.4/ha, and the yield level needed to make a 25% profit is 0.79-1.12 t/ha.

The development of soil conservation technologies is supplemented by breeding of new high yielding varieties with superior grain quality. The success of breeding to large extent depends on using

suitable genetic resources. Over the last three years the Institute actively restored its wheat germplasm collection by bringing varieties and lines from the institutes in Northern Kazakhstan (Pavlodar ARI, Karaganda ARI, Kostanay ARI), neighboring programs in Russia (Siberian ARI, Samarskiy ARI, Siberian Inst. of Plant Breeding) as well as from China, Mexico, CIMMYT, and ICARDA. The breeding center at present maintains a collection of about 2500 spring wheat entries from different countries all over the world, and is working to properly conserve and manage this diversity.

The Northern Kazakhstan Breeding Center was established in the Institute in 1971. Its major objective is to develop high yielding, superior quality, spring wheat varieties for different regions of the country. These wheat varieties should also combine cold and drought tolerance, pest and disease resistance with good lodging tolerance and good fertilizer response. The history of wheat breeding in Northern Kazakhstan is associated with the name of a talented breeder, Academician V. Kuzmin, who laid out the theoretical basis for breeding in the virgin lands of Kazakhstan. He developed more

Table 3. Cost (US\$) of spring wheat cultivation with different levels of input.

Expenses	100% of fuel and needed chemicals	100% of fuel with no chemicals	50% of fuel with no chemicals	33% of fuel (sowing-harvesting)
Seeds	26.4	26.4	26.4	26.4
Fertilizers	22.0	-	-	-
Pesticides	16.3	-	-	-
Fuel and electricity	21.2	18.5	12.6	7.7
Salary	6.6	4.8	3.9	3.3
Amortization & repair	35.6	29.7	21.1	17.3
Other expenses	38.4	23.8	19.2	16.4
Total	166.5	103.2	83.2	71.1
Grain yield needed to compensate for costs*	1.38	0.86	0.69	0.59

* Wheat grain price is \$120 per ton.

than 30 varieties of different agricultural crops. The breeders from Karabalyk Experiment Station also contributed to breeding efforts in Northern Kazakstan - breeder L.V. Pimenova released 20 varieties of bread and durum wheat.

The environmental conditions in the region require two types of varieties: intensive for high input and drought resistant steppe type. The first type is bred for areas with relatively good moisture supply (North Kazakstan, Kostanay regions, and fallow fields). The second type is suitable for the dry steppe of Northern, Central, and Southern Kazakstan. The most important traits for the first type are high yield potential, short vegetative period (for the Northern part: early maturity; for the dry steppe: intermediate maturity), cold tolerance, lodging resistance, good fertilizer response, resistance to fungal diseases and pre-harvest sprouting, tolerance to low temperature during grain formation and maturity. The steppe type varieties should be high yielding with superior quality, intermediate (for fallows) and intermediate to late maturing, drought and heat tolerant with good deep root system, enhanced photosynthesis of leaves and stems, resistant to root rots, and tolerant to low temperature during grain formation and maturity.

Several wheat breeding schemes are applied at the Institute (Tables 4-7). If F1 is grown in the greenhouse and the selection is made in F2, a variety can be bred in 7-8 years. The Institute, together with Akmola Agricultural University, developed two wheat varieties (Kenzhegali and

Table 4. A breeding scheme based on selection of wheat biotypes, 1996.

Year	Selection
1 st year	Selection of biotypes based on the grain gliadin pattern (1000 seeds)
2 nd year, fall	Multiplication in the greenhouse
3 rd year, spring	Multiplication in the greenhouse, field evaluation and grain quality test
4 th year	Preliminary yield trial of the best biotypes
5 th year	Yield trial
6-7 year*	Advanced yield trial, multiplication and multilocational testing.

* Following this procedure the variety Ishimskaya 90-22 (biotype) was developed and yielded 1.78 t/ha compared to 1.64 t/ha of Saratovskaya 29.

Table 5a. Pedigree of the spring wheat variety Akmola 40 (bred by A.I. Baraev Kazak Institute of Cereal Production).

Year	Cross-selection
1971	Cross Shortandinka 25/(pollen mixture of Aurora, Kavkaz and Yubileinaya) resulting in selection of Line 74
1978	Cross Line 74/Tselinnaya 21 resulting in selection of Line 74-1
1985	Cross Lutescens 36-74(VIR)/Line 74-1 resulting in selection of variety Akmola 40
1996	AKMOLA 40 – submitted to the official state variety testing

Table 5b. Comparative performance of varieties Akmola 40 and Saratovskaya 29.

Trait	Akmola 40	Saratovskaya 29
Days to maturity	82	82
Yield, t/ha	1.98	1.76
Protein content, %	15.4	16.1
Quality estimation, score	4.4	3.6

Table 6. Accelerated spring wheat breeding scheme used at the A.I. Baraev Kazak Institute of Cereal Production (1985-1996).

Conventional scheme	Accelerated scheme 1	Accelerated scheme 2	Accelerated scheme 3
Year 1	Year 1	Year 1	Year 1
Cross	Cross, greenhouse, field	Cross, field greenhouse	Cross, greenhouse
Year 2	F1, field	F1, greenhouse	Year 2
F1, field	F2, field selection	Year 2	F1, greenhouse
Year 3	F2, selection	Year 3	F2, greenhouse selection
F2, selection	Year 4	F3, field	Year 3
Year 4	F3, head rows	Year 4	F3, head rows
F3, head rows	Year 5	F4, greenhouse	Year 4
Year 5	F4, observation	F5, observation	F4, observation
F4, observation	Year 6	Year 5	Year 5
Year 6	F5, PYT	Year 6	F5, PYT
F5, PYT	Year 7	Year 7	Year 6
Year 7	F6, greenhouse	F6, PYT	F6, greenhouse
F6, YT	Year 8-10	Year 8-8	F7, YT
Year 8-10	F7-9, AYT	Year 9	Year 7-9
F7-9, AYT	Year 11	F10, On farm trial	F8-10, AYT, OFT
Year 11	F10, On farm trial	Varieties:	Varieties:
F10, On farm trial	Varieties:	Ishimskaya 88,	Ishimskaya 92
Varieties:	Tselinnaya 24,	Ishimskaya 90	
Tselinnaya 20,	Shortandinskaya		
Tselinnaya 21,	125,		
Shortandinskaya	Akmola 2,		
25	Akmola 3		

Table 7. Accelerated spring bread wheat breeding scheme using biotechnology (somaclonal variation). Joint project between the A.I. Baraev Kazak Institute of Cereal Production and Akmla Agricultural University.

Year	Activity
1	R0 – induction of callus from immature embryos, development of regenerated plants
2	R1 – multiplication of regenerated plants and their screening in the greenhouse R2 – observation nursery R3 – multiplication of the best lines
3	R4 – observation nursery
4	R5 – preliminary yield trial
5-7	R6-8 – yield trials R9 – submission of a variety for the State Testing

Varieties developed using this method: Kenzhegeli from variety Tselinogradka, Lutescens 94 from Ishimskaya 88, Dostyk from variety Omskaya 17. The yield of new varieties is 0.23-0.28 t/ha higher compared to Saratovskaya 29 (1.3 t/ha).

Table 8. Spring wheat varieties from North-Kazakstan Breeding Center released in the Republic of Kazakstan and Russia.

#	Variety	Year of release	Released for regions in Kazakstan	Released for regions in Russia
Varieties from A.I. Baraev Kazak Institute of Cereal Production				
1	Pirotrix 28	1968	North-Kazakstan	Novosibirsk
2	Tselinnaya 20	1978	East-Kazakstan, Semipalatinsk	Omsk, Chelyabinsk, Altay
3	Tselinnaya 21	1980	Akmola, Kokshetau, Kostanay, Pavlodar, Torgay, Semipalatinsk	
4	Tselinnaya 26	1986	Semipalatinsk, East-Kazakstan	Omsk
5	Tselinnaya 60	1986	Kokshetau	Altay
6	Tselinnaya yubileinaya	1988	Akmola, Kokshetau, Kostanay, Pavlodar Torgay	
7	Erytrospermum 35	1991	Kostanay, Kokshetau, Karaganda, Pavlodar, Zhezkazgan	
8	Tselinnaya 24	1993	Akmola	
9	Tselinnaya 3S	1996	Akmola, Kokshetau, Torgay	
10	Akmola 2	1998	Akmola	
11	Damsinskaya 90	1995	Akmola, North-Kazakstan	Chelyabinsk
12	SID 88	1993	Zhezkazgan, North-Kazakstan, Karaganda, Kokshetau	
Varieties from Karaganda Agric. Research Institute				
13	Karagandinskaya 70	1992	Central-Kazakstan, Karaganda	Novosibirsk
14	Karabalykskaya 90	1995	Karaganda, Kostanay, North-Kazakstan, Kokshetau	
Varieties from Karabalyk Agricultural Research Station				
15	Karabalykskaya 92	1997	Semipalatinsk	
16	Komsomolskaya 56	1990	North-Kazakstan	
17	Komsomolskaya 75	1996		Chelyabinsk

Lutescens 94) using tissue and cell culture. Spring wheat breeding and related research cover 18 different projects and are done in collaboration with Karaganda ARI, Pavlodar ARI, Kostanay ARI, and Akmla Agricultural University. During the period 1936-1997, these institutions developed more than 80 spring wheat varieties, and 51 of them were cultivated. During 1990-1996 some 17 varieties were released in different regions of Kazakstan and Russia. Several of them occupy substantial areas (Tselinnaya 20; 21; 26; Tselinnaya Yubileinaya, Tselinnaya 3S, Karagandinskaya 70, Eritrospermum 35 and others) (Table 8). The newest bread wheat varieties being introduced into production are Karabalykskaya 90; 92 (Karabalyk Exp. Station) Thelinnaya 3S, Akmola 2, Ishimskaya 92, and Shortandinskaya 125 (A.I. Baraev Kazak Institute of Cereal Production). Spring durum wheat occupies a much smaller area. The new released varieties are Damsinskaya 90 (Kazak Institute of Cereal Production) and CID 88 (Karabalyk Exp. Station). In 1996 A.I. Baraev Kazak Institute of Cereal Production submitted to the state official testing bread wheat varieties Dostyk and Akmola 40 and durum wheat Damsinskaya 40. Karabalyk Exp. Station submitted durum wheat Kostanayskaya 30. The following spring wheat varieties are currently being tested in the official state testing system: Akmola 2, Akmola 3, Lutescens 94, Shortandinskaya 95, Lutescens 268.

In the process of wheat breeding some research was conducted targeting better efficiency of selection for yield, quality, broad adaptation, drought tolerance and immunity to loose smut and stem rust. The following approaches were developed: selection of parents based on the size of the leaves; utilization of winter wheat in spring wheat breeding, and models of varieties for different yield levels. An accelerated breeding methodology was developed based on non-traditional methods. The utilization of dominant genes *Vrn3* and *Ppd* in breeding for earliness was studied. At present a study is being conducted to use convergent crosses targeting earliness, drought tolerance, yield, and quality. A method for evaluating drought tolerance was developed

based on seedlings' ability to synthesize proline. A method for selecting yield in the greenhouse was developed. The possibility of using protein markers for selecting genotypes with good grain quality was investigated. A laboratory method for estimating drought tolerance was developed taking into account the resistance of roots to different solutions.

In order to progress in spring wheat breeding in Kazakstan, the following steps should be implemented:

1. A CIMMYT outreach office should be established at the A.I. Baraev Institute of Cereal Production to facilitate conservation of wheat genetic resources and strengthen wheat breeding.

2. CIMMYT should support the planned research agenda of A.I. Baraev Kazakstan Institute of Cereal Production in breeding early varieties, seed production, biotechnology, immunity to diseases and grain quality.
3. The breeding center of A.I. Baraev Kazak Institute of Cereal Production will make its spring wheat genetic resources available to CIMMYT for targeted use in other countries.

Spring Wheat Breeding in Kazakhstan

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The Northern region of Kazakhstan is the main area of high quality wheat production. The dry climate, intense solar radiation, and fertile soils combine to produce grain with 14-16% protein content without nitrogen fertilizers (some years it may reach 17-18%). However, cereal cropping conditions are extremely harsh due to the brief (only 110-120 days) frost-free period, low precipitation, and high year-to-year variability. For instance, yield of widely grown variety Saratovskaya 29 in 1964-1995 varied from 0.66 t/ha in the very dry 1965 season to 3.65 in the very favorable 1986 season. Coefficient of variation for yield over this period was 30.8%.

New wheat varieties should combine contrasting traits such as cold tolerance at seedling stage in spring and drought and heat tolerance; drought tolerance at pre-anthesis with response to rainfall during grain fill and maturity; relatively high tillering capacity and uniform tiller development.

Starting in 1936 wheat breeding was based on step-by-step hybridization and selection of spring and winter genotypes and their derivatives. There were several stages in wheat breeding in Kazakhstan.

Stage 1 (1936-1955). Breeding of intermediate late maturing varieties combining cold tolerance at seedling stage for relatively early planting dates (end of April – beginning of

May) with long emergence to tillering period. Due to the long seedling-anthesis, this type tolerated drought in June well and provided a 15-25% yield increase over early maturing varieties. These properties were exemplified in varieties Akmolinka 1 and Shortandinka which occupied major areas up to the beginning of the 1960s. After virgin lands were brought under cultivation in 1954-56, these two varieties no longer satisfied producers due to poor quality and were replaced by introduced varieties such as intermediate maturing Saratovskaya 29 and intermediate-late variety Bezenchukskaya 98.

The second stage started in 1960 after a laboratory for evaluating grain quality was established and more emphasis was placed on breeding for bread making quality. A number of high quality varieties were released during 1967-88: intermediate-late maturing varieties (Tselinogradka, Pirotrix 28, Tselinnaya 20, Tselinnaya 21, Tselinnaya yubilenaya) and intermediate maturing varieties (Shortandinskaya 25, Tselinnaya 26, Tselinnaya 60). In the early 1960s, later sowing dates for spring wheat were introduced: May 15-25. Due to this, intermediate-late maturing, high yielding, and good quality varieties turned out to be too late to replace Saratovskaya 29. These varieties occupy 15-40% of the wheat area. Intermediate-late maturing varieties Shortandinskaya 25, Tselinnaya 26,

and Tselinnaya 60 did not have obvious advantages over Saratovskaya 29 and had limited distribution. During this stage it was realized that new varieties need to combine high yield, earliness, quality, and resistance to major diseases and pests.

This objective was partly implemented in the 1990s, when intermediate-early maturing variety Tselinnaya 24 and intermediate maturing varieties Tselinnaya 3S and Akmola 2 were released. However, these varieties are not widely cultivated. Tselinnaya 24 and Akmola 2 were recommended for cultivation in the Akmola region only.

Taking into account the requirements for high quality grain production in the Northern region of Kazakhstan, the following strategic breeding objectives are on agenda now: Development of drought tolerant, intermediate maturing varieties representing the steppe type of germplasm to complement early and intermediate-late varieties and stabilize grain production in the region. These varieties should have superior bread making quality with 14-16% grain protein.

If there was progress in breeding for quality, disease resistance breeding efforts basically failed. Starting in 1990 breeding for disease resistance practically stopped due to funding limitations and lack of

resistance sources. There is not a single variety that is resistant to leaf rust, stem rust, and septoria in the list of varieties recommended for Northern Kazakhstan. These diseases affect wheat production mainly during high rainfall years. Yield losses due to leaf rust, which is present annually in the steppe-forest zone, is estimated to be 15-30%. Stem rust epidemics caused tremendous yield losses. In 1960, 1964, and 1967 stem rust severity reached 60-90% over an area of 1.7-2.4 mln ha. In the Kostanay region only, wheat production decreased by 0.60-0.95 mln t. In some years septoria is as damaging as rusts. It has been observed more frequently over the

last 15-20 years. In wet, cool years the infection level may reach 80-100%. As a result the crop suffers yield losses of up to 50-70% with considerable decrease in grain quality.

It is well known that the best way to protect the crop against disease is breeding resistant varieties. This type of breeding unfortunately has not been developed up to now due to a number of reasons: complete lack of funding for breeding for resistance to different pathogens; lack of reliable sources of resistance to leaf and stem rust and septoria; lack of knowledge on the variability of pathogens populations and their biology; very limited financial resources to buy rust and septoria inoculum; lack of

equipment and resources for artificial inoculation (plastic film, irrigation, syringes, spore distributors, etc.).

The strategic short term objective of wheat breeding is the development of relatively early, drought tolerant, high quality varieties with resistance to major pathogens and suitable for machine harvesting. This work requires financial and other types of resources. If such varieties are developed, Kazakhstan will be able to produce and sell on the world market high quality bread wheat and durum wheat with 14-18% protein content.

Spring Wheat Breeding in Western Siberia

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Ecological conditions in Western Siberia, a unique and important region for the Russian economy, are characterized by high variability of the main weather factors across years, seasons, and days, high insulation, lack of precipitation, especially in summer, strong winds, and soil erosion. Due to these factors, yield variability is also high, especially in the steppes.

The success of wheat breeding is obvious, especially during the last 15 years. However, the potential yield of varieties with acceptable quality is often not realized. There are several reasons for this:

1. The overall interest in breeding high input varieties resulted in the loss of broad adaptation, which is essential for most agricultural regions in Western Siberia.
2. The lack of technologies for new varieties does not allow full expression of their genetic potential.
3. The level of agronomy is not high in many farms. High input varieties are more sensitive to low input technology compared to varieties with broad adaptation.

Thus, for local environments development of broadly adapted varieties is essential.

According to the State List of Released Varieties (1997) there are 40 spring bread wheat varieties

recommended for Western Siberia. Varieties with intermediate-early maturity and intermediate maturity comprise 65% of the list; the other 35% is varieties with intermediate-late maturity. Superior, high quality varieties constitute 88%. The distribution of released varieties according to development method is as follows: 91.4%: through hybridization followed by individual plant selection; 5.7%: by selecting cultivated varieties or genetic resources (Pirotrix from Shortandinka, Tyumenskaya rannyaya from Vavilov Institute's accession Pollo) and 2.9%: by mutageneses (Novosibirskaya 67). The distribution of varieties according to geographic origin of the parents is the following: parental varieties from Siberia, Volga region, and Kazakstan: 55.9%; accessions from the Vavilov Institute collection: 28.8%; and winter wheat varieties: 15.3%.

Varieties grown in Western Siberia are characterized by the following traits:

1. High yield potential (5.5-6.5 t/ha); however, its variability in all climatic zones is very high.
2. Lack of early maturing varieties.
3. Adaptation to the ecological conditions of the region including frequently occurring droughts. However, there is poor resistance to abiotic stresses occurring during maturity and harvesting such as lodging, preharvest sprouting, and grain shattering.

4. Inadequate resistance of cultivated varieties to widespread diseases in the region. There are no varieties that combine resistance to several diseases.

The following breeding objectives take into consideration ecological conditions, regional production requirements, and availability of genetic variation:

- development of varieties with different maturities, which are less labor and energy consuming;
- yield stabilization through reducing crop losses due to biotic and abiotic stresses;
- development of varieties with good milling and bread making qualities, and high nutritional value.

We have chosen the following major targets for spring bread wheat breeding:

- yield potential;
- grain quality;
- broad adaptability (cold, drought, and heat tolerance, efficient use of precipitation, especially in July);
- disease resistance (powdery mildew, different rusts, septoria, etc.);
- tolerance to lodging and preharvest sprouting;
- response to fertilizers.

Table 1 shows the efficiency of spring wheat breeding. Revival of breeding in the 1980s is due to the

return to classic breeding methods, their creative review, development of modern infrastructure, and new methodology for germplasm evaluation.

Nine varieties from the Siberian Institute are cultivated in Russia and Kazakhstan, including six varieties with superior bread making quality (Omskaya 9, Irtyshanka 10, Omskaya 18, Omskaya 19, Omskaya 20 and others). These varieties are listed in Table 2.

Most varieties cultivated at present possess the following traits:

- good cold and heat tolerance;
- a combination of traits rarely found in one genotype: drought and lodging tolerance; high yield potential and good grain quality;

- very broad adaptation as shown by the fact that varieties developed at the Institute are grown over a vast area.

The new generation of varieties has higher yield potential and better grain quality than their predecessors. The yield potential of new varieties depends on environmental conditions, but most importantly, its lower limit is significantly higher than that of old varieties from the same maturity group (Table 3). The data in Table 3 refute the assumptions of several researchers that the adaptation of new varieties is poorer.

The recombination (transgressive) breeding scheme is based on four subsystems:

- parental germplasm;

- hybridization;
- selection of recombinants and testing their progeny;
- comparative evaluation of germplasm.

The theory of plant breeding is based on the doctrine of the value of parental germplasm and the centers of origin of cultivated crops as well as the law of homologous series of inherited variability, the law of discrete nature of trait hereditability, chromosome theory of heredity, natural and artificial selection theory, the theory of pure lines, genotype, and phenotype; the principle of individual selection and progeny test, studying the plant-plant community relationship and how it is influenced by the environment.

In accordance with the principle that the theoretical and methodological level of breeding determines its progress, we never stop looking for ways to enhance it. In particular, we developed approaches for assembling a working germplasm collection based on the combining ability of numerous advanced genotypes for the most valuable traits. We also developed new ways of classifying methods of emasculation, pollination and types of crosses. The pollination technique was improved and patented.

Though we support using genetically diverse germplasm in crosses, most crosses are made with released varieties and advanced breeding lines (Table 4). In 1991-95 the Department of Spring Wheat Breeding submitted six varieties for the State Testing. Three of them have intermediate-early maturity and three possess intermediate-late maturity.

Table 1. Varieties from the Siberian Agricultural Research Institute submitted to the State Variety Testing Commission and released (1920-1993).

Period	Number of varieties		% released varieties among varieties submitted to the State Variety Testing
	submitted to the State Testing	released	
1920-1936	20	6	30.0
1937-1950	20	1	5.0
1951-1960	0	0	0
1961-1970	5	0	0
1971-1980	11	4	36.4
1981-1993	7	5	71.4

Table 2. Spring bread wheat varieties included in the State List of Released Varieties, 1997.

Variety	Year of inclusion in the State List	Target region*
Omskaya 9**	1979	X, XI
Irtyshanka 10**	1981	VII, X, XI
Omskaya 12	1984	X, XI
Omskaya 17**	1986	VII
Omskaya 19**	1989	
Omskaya 18**	1991	IX, X
Omskaya 20**	1993	IX-XI
Omskaya 24	1996	X
Omskaya 28	1997	X

* Region: VII – Mid Volga, IX – Urals, X – West Siberia, XI – East Siberia

** Varieties grown in Kazakhstan too.

Table 3. Yield performance of spring bread wheat varieties developed by Siberian Agricultural Research Institute (1929-1993).

Variety	Year of release	Yield in 1989-1994 (t/ha)	
		Average	Min-max
Milturum 321	1929	2.59	0.43-2.59
Tsezium 111	1929	2.47	0.38-3.09
Milturum 553	1940	1.78	0.33-2.15
Irtyshanka 10	1981	2.70	0.81-3.67
Omskaya 17	1986	2.68	1.11-3.86
Omskaya 18	1991	3.16	1.50-4.42
Omskaya 20	1993	3.38	1.49-4.37

Five of them have superior bread making quality. Varieties Omskaya 26, Omskaya 28, Omskaya 29, Omskaya 30, and Omskaya 31 were officially tested across a number of locations in Russia and Kazakstan in 1997.

The following factors contributed to the success of wheat breeding at the Institute:

1. Increase in the total number of breeding nurseries and entries (up to 40-45,000 entries), especially in early generations (segregating populations, head rows, and observation nurseries) (Table 5).

2. Improvement of hybridization techniques that allowed increasing the number of crosses made per year to 600 and the number of hybrid kernels per cross to 80-100.

3. Utilization of greenhouses and growth chambers and improvement of the breeding scheme.

4. Improvement of the breeding methodology (evaluation of parental germplasm, improvement of hybridization and selection of parents, development of ecological basis of breeding, etc.).

5. Utilization of small-size agricultural machinery for field work and preparation of nurseries.

Good potential of utilization of winter wheat genotypes in spring wheat breeding has to be mentioned. This approach was used for the first time in the Institute in 1925. However, the first results of this technique were obtained only in the 1980s. In 1979 Omskaya 9 was released. It was selected from a cross involving outstanding variety Bezostaya 1. Later the winter wheat genotypes were used to develop such varieties as Omskaya 17 (winter wheat Mironovskaya 808), Omskaya 18 (winter wheat from the US Heyness), Omskaya 19 (Bezostaya 1 and Mironovskaya 808) and Omskaya 20 (winter wheat Kavkaz). Winter wheat breeding is more advanced than spring wheat breeding, especially in yield potential. Crosses between genotypes with different growth habits result in successful transgressive recombinants.

Natural conditions in Siberia are severe. Ecological factors (temperature, rainfall, high degree of soil cultivation in the presence of strong winds) that are important for plant growth and development are unstable and sporadic. This sometimes forces breeders to work for combining the opposite traits. Here success is unattainable without breeding for adaptation.

The Department of Spring Bread Wheat Breeding consistently takes into consideration the changing ecological conditions for wheat production in the region. In particular, we coined the term

Table 4. Utilization of different parental germplasm in crosses (1971-1995).

	Average number per year				
	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995
Number of crosses	236	301	310	372	458
Number of genotypes used in crosses including	64	102	93	110	135
- Released varieties and breeding lines	27	58	60	58	110
- Vavilov Institute accessions	19	22	17	31	17
- Winter wheat varieties	13	11	15	15	3
- Other species	5	11	1	6	5
Total number of hybrid seeds	42,534	51,173	44,257	22,348	24,617
- Average per combination	180	170	143	60	56

Table 5. Number of genotypes studied in breeding nurseries (1976-1997).

Nursery	Number of entries		
	1976-1995	1996	1997
Collection	401	496	248
Hybridization			
Number of crosses	368	458	500
Total number of kernels obtained	40,535	12,010	20,000
Number of kernels per cross	110	21	40
Head Rows	28,035	15,000	11,000
F4, Observation nursery	1,284	700	900
Including feeding wheat	144	160	93
F5, Observation nursery	216	190	126
Including feeding wheat	60	33	36
Advanced yield trial, after fallow, 1 st planting date	70	69	56
Advanced yield trial, after fallow, 2 nd planting date	36	15	20
Advanced yield trial, after cereals	4,1	24	26
Including feeding wheat	2,8	43	75
Multilocal yield trial	2,5	12	-

“ecological plasticity”. In a number of papers by the author and his post-graduate students V.A. Sapega, V.V. Meshkov, I.A. Belan and others, a system for evaluating germplasm for ecological plasticity was suggested. Traits that are important for broad adaptability or ecological plasticity were determined. Germplasm resistant to abiotic and biotic stresses was identified.

According to A.F. Reymers, adaptation is the combination of the reactions of a living system that supports its ability to function when the environment changes. Adaptation is characterized by vigor of the organisms, their ability to compete. The diversity of adaptation indicates that while developing adaptive varieties breeders are not using the entire scope of adaptive reactions. The latest research of electrophoretic spectrum, and in particular, the components of gliadin (protein of wheat) enriched our understanding of the composition of varieties which sometimes consist of different biotypes (Omskaya 9, Omskaya 18, etc.). This research should be widely applied in seed production because in the process of variety reproduction a shift in population composition is possible. On the other hand, this shift may result in improved adaptation to a local environment.

In breeding for adaptation we should use more the polymorphisms within the genus *Triticum* since its many species possess very valuable traits. Several species should be considered in breeding for

biologically and economically valuable traits such as:

- early maturity – *T. dicoccum* (Schrank) shuebl., *T. compactum* host.;
- adaptation to harsh environment – *T. spelta* L., *T. monococcum* L.;
- cold tolerance – *T. aethiopicum* Jakubz., *T. persicum* Vav., *T. compactum*;
- drought and heat tolerance – *T. dicoccum*, *T. vavilovii* (Thum.) Jakubz., *T. sphaerococcum* Perciv., *T. petropavlovskiyi* Udacz. et Migusch., *T. dicoccoides* Schweinf.;
- salt tolerance – *T. turanicum* Jakubz.;
- disease and pest resistance – *T. monococcum* L., *T. sinskajae* A. Filat. et Kurt., *T. zhukovskiyi*, *T. militinae*, *T. kuharae*;
- lodging resistance – *T. sphaerococcum*, *T. monococcum* L.;
- preharvest sprouting resistance – *T. persicum*;
- resistance to grain shattering – *T. vavilovii*, *T. timopheevii*;
- yield components (tillering, number of kernels per spike, etc.) – *T. ispahanicum* Heslot, J. macha Dek. et Menabde, *T. vavilovii* (number of kernels per spike up to 95);
- high protein content – *T. urartu* Thum. ex Gandil., *T. dicoccum*, *T. dicoccoides*, *T. boeoticum* Boiss.;
- bread shelf life – *T. turanicum*;
- high increase in loaf volume (85% versus 40-50% in bread wheat) – *T. turanicum*;
- high contents of B₂ and PP vitamins – *T. dicoccoides*;
- response to high input – *T. persicum*.

The current tendency of “ecologization” of biological science (genetics, breeding, crop production) is well justified in our opinion.

Ecological breeding is a combination of methods and techniques to develop varieties and hybrids with maximum and sustainable productivity in their target environment by applying ecologically safe crop technology and a minimum number of chemicals. According to the above definition of ecological breeding, its main objectives are:

- adaptation of breeding;
- breeding of low energy consuming varieties;
- breeding for low content of pollutants in the production.

There are several obvious reasons to develop the theory of ecological breeding for Siberia:

- 1) continental climate;
- 2) high prices for mineral sources of energy;
- 3) environmental pollution.

Taking into consideration the fact that a variety is the basis of crop production, its role is now critical as the basis of “biologization” of farming.

Considering the different forms of property of the holdings, their sizes and economic conditions, we offer varieties for production that vary both in maturity (from intermediate-early to intermediate-late maturity) and input response (intensive and semi-intensive varieties). In addition, we also develop bread wheats with high yield potential and suitable for production of high quality pasta as well as feed varieties to meet the current demand.

We expect that the success of breeding for adaptation in the future will be connected with the following factors:

1. The genus *Triticum* L. has great variability of adaptation reactions. Accordingly, the use of diverse species in hybridization has huge potential for developing new varieties resistant to unfavorable ecological factors.
2. While creating a variety, a breeder comes across several levels of live tissue organization. For instance, with recombination or transgressive breeding certain processes take place on cellular

level (merging of parental gametes in hybridization) and others - on plant population level (yield trials and on-farm trials). During this natural process new emergent traits can appear which are not specific for the previous levels. It is natural that the organization and management of the systems on different levels are different. Studying these processes will enhance the efficiency of breeding especially at its early stages.

The high priority areas of breeding in the future will be improvement of resistance to pests, diseases, and

stresses as well as quality enhancement utilizing the newest achievements in genetic engineering and cellular breeding.

We believe that the potential of breeding to increase productivity has not been exhausted yet. Implementation of these opportunities under severe Siberian conditions must be based on the development of theoretical foundations of breeding for adaptation based on ecological genetics. Breeding for resistance to biotic, abiotic, and anthropogenic factors is also important.

Research on Spring Wheat Technology in Northern Kazakhstan

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Spring wheat occupies 95% of the wheat area in Kazakhstan, 75% of which is in the Northern Region. Wheat is grown in the steppes and forest steppes on black soils and chestnut soils. Kazakhstan has a continental climate characterized by very cold winters and hot summers, little rainfall (220-420 mm annually), and frequent wind.

The components of spring wheat production technologies are applied throughout the year. That is why meteorological conditions in a particular year or season are important. Knowledge of weather patterns is essential to applying the technology in the most suitable fashion to increase grain production. In 62% of the years in two autumn months (September and October), there is average or slightly higher rainfall (52 mm). However, every five years there is a possibility of dry weather during this period, which determines the quality, method, and possibility of soil tillage and fertilizer application.

Precipitation distribution in winter is also very stable. In 58% of years precipitation is about the long term average or higher (97 mm). With snow retention it is possible to significantly increase the moisture accumulated in the soil. At present many farms have facilities for snow retention, and it is also possible to

store the snow because the area under crops is 3.5 times smaller than all agricultural lands.

Spring is dry in 35% of years and moderately rainy in 44% of years, that is, the probability of average conditions is very low. The contrast in weather conditions in spring is the main reason for the fact that the data on early spring harrowing and subsequent soil cultivation are contradictory. In early and dry springs if wheat is sown after the 23rd of May there is high probability that early spring harrowing and soil cultivation will have a positive effect on yield.

Most precipitation in Northern Kazakhstan falls during the summer months: 140 mm in black soil zone and 96 mm in chestnut soil zone. This constitutes 40% of the annual average. Based on long-term observations, rainfall in July is the highest (55 and 38 mm, respectively, in black soil and chestnut soil zones), August is drier (45 and 26 mm), and June is drier still (40 and 31 mm). Relative frequency of years with maximum rainfall in June is 26%, July, 45%, and August, 29%. The probability of drought (hydrothermal coefficient < 0.5) in June is 42-44%, in July, 31-42%, and in August, 31-36%. The average hydrothermal coefficient of three summer months in black soil zone is 0.78 and in dark chestnut soil zone is 0.55.

Early fall frosts should be seriously considered. Their probability in August is in 19% of years and before August 28th, in 13% of years. Thus, if we sow on the 15th of May we have 105 days from sowing time to the dangerous date of frosts, if we sow on the 20th of May we have 100 days, if we sow on the 30th of May we have 90 days.

For the last 25 years when planting on black soils after fallow and after cereals from the 10th of May until the 4th of June with a 5-day interval, the frequency of the gluten content of bread wheat variety Saratovskaya 29 at the level of 23-27% was 14.7%, 28-31% - 54.7%, 32-35% - 28.2%, 36% and higher - 2.4%. Thus, the frequency of obtaining superior quality of grain as judged by the amount of gluten is 85.3%. This data clearly indicate that independently of the preceding crop and weather pattern for a particular season, the climate of Northern Kazakhstan allows obtaining superior quality grain of spring wheat.

The most favorable soil moisture conditions, their rational use for realizing yield potential and the highest content of nitrate nitrogen in the soil is observed in wheat sown after black fallow. The experiments conducted on Southern black carbonate soils during the last 27 years (1968-1973, 1981-1996) showed that the highest average yield of

spring wheat (1.84 t/ha) was obtained after black fallow. Grain yields of the second and fourth crops after fallow were 1.60 and 1.45 t/ha, respectively. After oats and maize, wheat yields are 16-17% lower compared to sowing after fallow.

Depending on the precipitation pattern during summer, the preceding crops influence wheat yields in different ways. When there is maximum rainfall in June, different preceding crops have low influence on yield. When there is maximum rainfall in July with wheat planting as the 2nd, 3rd and 4th crop after the fallow, yield decreases by 14, 18 and 22% respectively due to unfavorable conditions during tillering, booting and soil moisture deficiency at heading after non fallow. In such years spring wheat yield after fallow is 21% higher compared to after non-fallow. In the case of maximum rainfall in August the decrease in yield after non fallow is the highest and the yield level is 1.01 –1.49 t/ha. Hence, the difference in spring wheat yield between fallow and cereal predecessors in case of maximum rainfall in June is 7.8%, in July 21%, in August 29.1%. Fallow in the years with maximum rainfall in July and August provides better conditions for spring wheat and on average increases yield by 24.2% compared to non-fallow predecessors.

If plant protection chemicals and fertilizers are not available, fallow is the only option to obtain stable grain production. If there is no snow retention, a fallow field is the only way to collect sufficient moisture and then control weeds by cultivation. At present, fields that are good from agronomic point of view comprise no

more than 30% of all cereals fields. Considering data on the farming system, technological discipline in the farms and, probably, the pattern of late summer precipitation in Northern Kazakhstan, it is possible to say that the four field cereal-fallow rotation is the most acceptable option for many farms at present. This does not exclude using two- or three-field rotations. For land with lots weeds and no herbicides available, it would be logical to employ intensive mechanical tillage in summer and to transfer to the four-field cereals-fallow rotation in 2 or 3 years. However, it should be remembered that with the long-term use of two or three fields cereals-fallow rotations, the amount of humus and its quality deteriorates. And humus is the basis of landscape farming. In such rotations the organic residues are not sufficient to compensate for the mineralization process.

It should be emphasized that these recommendations are given for the transitional period from technologies using pesticides and mineral fertilizers to technologies without them. This period is the most difficult because the ecosystem is in the state of transition from one level of development to the other. This process is accompanied by some negative processes including the increase in weeds in the fields. As a rule, the duration of transitional period is 3 to 4 years. If during this period the farmer can effectively control weeds, then in the future they will not be a serious problem for him.

Reduction of black fallow from 25 to 20% presumes nitrogen fertilizer application. In case of nitrogen deficiency, grain yield decreases.

Considering that in recent years not only positive but also negative consequences of nitrogen fertilizer application were revealed, it is more effective to have two types of rotations – fallow-three wheat fields and continuous wheat sowing with application of herbicides and fertilizers. The grain yield from one hectare with this system of crop rotations will be 0.05 tons higher compared to the 5 field cereal-fallow rotation: fallow - four wheat fields.

In case of monocropping and lack of chemicals, the best option for rotation system will be fallow- three wheats, fallow – two wheats-perennial grasses in a separate field. With such structure of land use when 33-50% of wheat fields will be planted after black fallow, it is reasonable to go back to disk seeding machines on black soils with installation of hoe furrow opener along the tractor's wheel tracks and using caterpillar tractors. This will increase the effectiveness of black fallow, enhance yield by 10-15% and labor productivity during sowing by 20-30%, improve the uniformity of maturity of wheat and accelerate wheat maturity by 3-4 days.

The optimal dates for spring wheat sowing depend on rainfall distribution in spring and summer. With the July maximum in rainfall, sowing date does not affect yield very much ($V = 3.4\%$ - low variation). Such years are the most favorable for wheat production. Obvious decrease in productivity is observed with the late sowing date - the 4th of June. With the maximum of moisture in July the optimal sowing dates are 20-30 of May. When the sowing is done on the 5-15 of May, yield is lower due

to unfavorable conditions during tillering and booting when the spikes, flowers and anthers are formed and the number of kernels in a spike is determined. With the maximum level of precipitation in August only if sowing occurred very late the critical stages of plant development take place at the same time as the rainfall, but at the earlier dates of sowing yield potential decreases a great deal. As a result, yield in such years is very low. There is significant reduction in yield at early sowing ($V = 14.9\%$). In the years with uniform rainfall (and there can be contrast in moisture conditions: from very dry 1982 and 1984 to favorable with even distribution of rainfall in 1986 and 1992), the highest yields were obtained when wheat was sown from 15 to 30 of May. The yield reduction at the early and late dates is the biggest ($V = 15.1\%$).

According to the results of experiments conducted for 36 years at the A.I. Baraev Kazak Institute of Cereal Production, the maximum yield of medium maturity wheat varieties (1.64-1.65 t/ha) was obtained when it was sown on May 20 to 30. However, the relative frequency of formation of superior quality grain was high (88%) when it was sown between the 20th and the 25th of May, and 69% if planted on the 30th of May. The proportion of high quality seed reaches 78-85% in these years.

Rainfall distribution by growth and development stages of spring wheat shows that rainfall during tillering-booting and tillering-heading as well as rainfall before heading correlates well with grain yield. With the same

rainfall during pre-anthesis, sowing at the end of May enhances water availability by 31% during booting-heading and by 18% during heading-milk maturity as compared to sowing at the end of the first decade of May. Changes in the structure of the arable land in favor of increased proportion of fallow and use of hoe furrow opener sowing machines require adjusting the optimal dates for spring wheat sowing.

The optimal dates for sowing varieties Tselinaya 24, Tselinaya 90, Tselinaya Yubileynaya are earlier. Intermediate-early maturing variety Tselinaya 24 provides the maximum yield if sown on 20-25 of May. Its yield potential is equal to that of Saratovskaya 29 but it matures 3-4 days earlier. Intermediate maturing Tselinaya 90 decreases its yield to a lesser degree if planted after non fallow and provides high grain yield in the years when leaf rust and Septoria blotch are common. Intermediate-late maturing variety Tselinaya Yubileynaya develops more slowly during drought and benefits from late rains and warm fall. Out of 9 years of experiments the significant yield increase due to variety was obtained in three years.

The rule that the intermediate-late maturing varieties should be sown before the intermediate maturing ones, and the latter before intermediate-early maturing varieties is not correct in all years. For instance, in 1991 intermediate-early variety Tselinaya 24, sown on the 25th of May demonstrated the highest yield increase (0.42 t/ha) compared to planting on May 10 and intermediate maturing variety

Saratovskaya 29 demonstrated the highest yield sown on May 29-30 (0.34 t/ha).

The variation in seeding rate of spring wheat from 2.5 to 4.5 million viable seeds per hectare does not affect yield. The optimal seeding rates depend on moisture conditions, presence of weeds, variety characteristics and predecessors. The main target of setting the optimal seeding rate must be to obtain maximum yields with minimum seeds. Thus, in 1986-1994 the seeding rate of 2-3 mln seeds/ha provided the highest yield on Southern black carbonate soils. The respective yield for wheat after fallow planted with 1.5, 2.0, 2.5, 3.0 and 3.5 million of viable seeds per hectare was 1.74, 1.82, 1.83, 1.85 and 1.87 tons per hectare; wheat after wheat – respectively 1.57, 1.61, 1.67, 1.67 and 1.66 tons per hectare. The cost of seeds with the above mentioned rates is US\$13.0, 17.3, 21.6, 25.9 and 30.2 per hectare. Normally the cost of seed is US\$28-34. This can be reduced to US\$22-26 and the difference could be used to purchase pesticides.

Supporters of reckless "biologization" of farming call for stopping the application of mineral fertilizers and pesticides completely. However, the experimental data show that the yield of spring wheat planted after fallow on southern black soils without fertilizer does not exceed 1.0-1.1 t/ha and in very dry years even 0.6 t/ha, and if planted as the second crop after fallow - respectively 0.70-0.75 and 0.3 t/ha. The yield potential which can be easily achieved with fertilizers is 1.9-2.3 t/ha, and in favorable years even 4 t/ha.

Based on statistical analysis of long-term experimental data, the contribution of meteorological conditions and different elements of farming system (predecessors: black fallow, oats, wheat, barley; technology: simplified, regular and high input) on spring wheat yield was determined. The analysis showed that spring wheat yield is highly influenced by the technology applied - 40.1% of the overall variation; meteorological conditions - 40.8%. Only 3.4% of yield variation was attributed to predecessors.

Thus, the contribution of technology to overall spring wheat yield variation can be compared with the contribution of weather conditions. All this proves the importance of optimization of cultivation technology, and further improvement of some elements of the farming system which must be directed towards further reduction of the effect of unfavorable meteorological factors by the rational use of soil and climatic resources, application of fertilizers, herbicides, soil tillage, improvement of the technology of sowing and optimization of rotation structure.

To increase stability of grain production over years with variable weather patterns, the elements of agricultural technology must be implemented taking into consideration evaluation of existing and expected weather conditions.

Spring Wheat Production Technologies in Western Siberia

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Spring wheat is the main cereal crop in Western Siberia. The main planting area in the Omsk Region (about one mln ha) is situated in the steppes and forest-steppes (77%). In areas sown to spring wheat, the target for yield is 2.6-2.8 t/ha after fallow and 1.8-2.0 t/ha after other good previous crops. Introduction of advanced high input technologies will increase high quality grain production by 600-650 thousand tons.

The basis of spring wheat production increases is the development of high input cultivation technologies, such as:

- moisture accumulation and soil conservation measures;
- high-input varieties;
- application of chemicals including integrated weed, pest and disease control;
- optimization of plant nutrition by application of mineral fertilizers.

Characteristics of spring wheat cultivation

Place in crop rotation. Spring wheat is grown in specialized cereals-fallow or cereals-fallow-row crops rotations and planted after fallow, second crop after fallow or after maize. It is also possible to sow it after annual grasses, row crops and peas. The proportion of black fallow in specialized rotations in the steppes is 20-25%; in the forest-steppes, it is 17-20%.

Preparation of black fallow. In the steppes and southern forest-steppes, tillage starts in fall with subsoiling machinery. In summer soil is cultivated to a depth of 8-12 cm. For control of root weeds, chemicals (2.4-D, roundup) are applied. In the first decade of July, mustard is planted to serve as a windbreak. The contribution of black fallow to yield increases in the steppes is 28%, in the southern forest-steppes it is 17%, windbreak fallow - 0.27 t/ha.

Fall soil preparation. In the steppes after non-fallow land is prepared utilizing a subsoiler. In the absence of rainfall in autumn in weed-free fields and with moisture available in the topsoil layer (0-50 cm) less than 20 mm, the soil is not tilled (excluding complex soils and slopes). In the forest-steppes, except for the regions affected by erosion, a combined tillage system is applied (alternating plowing and subsoiling). Grain increase due to the introduction of soil conservation technology is 0.22 t/ha in dry zone.

Varieties. In the steppes according to maturity range, there should be up to 50% of varieties of intermediate-late maturity type (Omskaya 9 and 18) and up to 40-50% of intermediate maturity type (Sibakovskaya 3, Omskaya 20, Irtyshanka 10). In southern forest-steppe - 30 and 60%,

respectively, varieties Omskaya 26 and Omskaya 28 are promising for multiplication.

Optimization of sowing and harvesting time. Sowing dates are determined for each soil type, climatic zone and variety. Seeding rates are changed in accordance with the moisture availability and weather conditions before planting. The proportion of the crop harvested and threshed directly versus separate harvesting depends on crop stand, number of weeds and the weather. The contribution of optimum planting and harvesting dates to yield increases in the steppes is 35% and in the southern steppes, 25%.

Fertilizers. To balance the nutrients in fallow fields (considering the presence of nitrogen and moisture in soil), superphosphate is applied at a dosage of 60-80 kg of active ingredient per hectare. The application depth is 8-10 cm. When there is lack of superphosphate, it is applied in rows during planting - 40-60 kg of active ingredient per hectare. After non fallow, complete mineral fertilizer is applied, 40-60 kg of nitrogen and phosphorus per hectare. With high nitrate concentration in the upper 40 cm of soil, superphosphate is applied, with medium concentration - ammophos, with low concentration - nitroammophos at a

rate of P_{40} . The contribution of fertilizers to yield increase is 15% in steppe zone and 18% in southern forest-steppes.

Weed control. The most harmful group of weeds in the region are root spreading weeds, which can reduce yields by 50%. Agronomic protection measures are complemented by the application of 2,4-D herbicide at a rate of 0.8-1.0 kg of active ingredient per hectare, which decreases the number of weeds by 66-68%. If there are 2,4-D resistant weeds, diamet-D is applied at a rate of 1.2 kg of active ingredient per hectare, dialen - 0.8 kg of active ingredient per hectare, which decreases weeds population by 80%. Application of these herbicides provides grain yield increases of 0.17-0.24 tons per hectare. To control wild oats karakhol (suffix) is recommended – 2 kg of active ingredient per ha which kills 87-93% of weeds. Millet-type of weeds are controlled by illoxan – 1.1-1.6 kg per hectare. For steppe and southern forest steppe herbicides should be applied on 50-60% of the area.

Disease control. When the symptoms of leaf rust and powdery mildew appear, CINEB (3 kg per hectare), baleyton (1 kg per ha) and TILT-250 (0.5 kg per ha) are used. When there is a technological track available in the field, tank mixtures of fungicides with herbicides and nitrogen fertilizers are applied. On average in 5 years (1986-1991) the yield increase of spring wheat after fallow with chemical weed control was 0.22 t/ha (10.1%), after maize 0.28 t/ha (12.5%). In epidemic years the yield increase is 0.4-0.6 t/ha.

Pest control. Control measures are planned considering predicted pest population increases depending on economic threshold (wheat beetle - *Phyllotera vittula*, Swedish fly - *Oscinosoma pusilla*, beet webworm - *Loxostege stricticalis*, thrips - *Haplothrips tritici*, grain moth - *Hadena* sp.). Chlorophos and metaphos, BI-58, sumi-alfa are normally applied (0.5-1.5 kg per hectare). As soon as the pests appear, the chemicals are applied to the borders of the fields. The yield increase in wheat after fallow is 0.35-0.4 t/ha, after non-fallow predecessors - 0.15-0.2 t/ha.

Lodging control. Lodging appears mainly in moist years when the crop stand is dense. The harvesting is complicated, grain formation and grain quality deteriorate. The rate of the retardant (CCC) used in moist years is 6 liters per hectare, and in dry years it is 3.5-4.0 liters per hectare. Application is done at tillering possibly together with herbicides. The average yield increase due to application of retardant in 1986-1991 was 0.28 tons per hectare (12.9%) for wheat after fallow, and 0.17 tons per hectare (6.9%) for wheat after maize.

Nitrogen fertilizer. In the steppe and forest steppe zones, wheat planted after fallow does not need nitrogen fertilizer. However, in years with favorable moisture regime to improve the grain quality, late

nitrogen (N_{30}) spray application is effective. In 1986-1991 the average increase in grain yield of the variety Omskaya 9 after fallow due to nitrogen application was 0.35 tons per hectare (12.3%).

Technological wheel track. Intensive technology of spring wheat cultivation requires multiple passes of machinery across the field to apply pesticides, fertilizers and other substances during different phases of wheat development. With this in view at sowing the technological wheel track is left to let the spray devices (PSU, OP-1600, ON-400) pass. This improves the quality of work. All the wheat fields at the Omskoye Experimental Demonstration Farm, where intensive technology is fully applied, are cultivated using a technological wheel track.

The application of intensive technology of spring wheat cultivation in the experiments of Siberian Agricultural Research Institute in steppe (Table 1) and in southern forest-steppe (Table 2) resulted in substantial yield increases.

Positive experience in growing spring wheat using intensive technology and research results in Siberian ARI exists at the Omskoye Experimental Demonstration Farm and in Altay ARI at the Dokuchaev Experimental Demonstration Farm, where grain yield is twice as high as in other farms of the region.

To grow spring wheat using progressive technology that provides a 30-50% yield increase, the following chemicals are necessary (per 1000 hectares):

- phosphorus fertilizers	- 50-60 tons of active ingredient;
- nitrogen fertilizers	- 25-25 tons of active ingredient;
- herbicides, group 2.4-D	- 700 kg of active ingredient;
- wild oats herbicides	- 800–1000 kg of active ingredient;
- millet-type weeds herbicides (illoxan and puma-super)	- 700 kg of active ingredient;
- fungicides (bayleton or TILT)	- 300-500 kg of active ingredient;
- insecticides (one of the following: chlorophos, carbophos, metaphos, BI-58, sumi-alfa)	- 300-500 kg of active ingredient
- CCC	- 2.5 tons
- seed dressing (one of the following: vitavax 75 s.p., fundazol, granozan)	- 400-500 kg of active ingredient

Table 1. Wheat yields (t/ha) with different methods of soil cultivation and chemical application in Steppe Zone of Omsk Region (1991-95).

Tillage	Wheat after fallow		Wheat 4 th crop after fallow	
	1*	2*	1*	3*
Plow (every year)	2.54	3.23	2.08	2.81
Subsoiling	2.59	3.31	1.91	2.72
Minimum tillage	2.42	3.29	1.64	2.81
Zero tillage	2.24	3.20	1.45	2.62

Source: Y.B. Moshchenko.

* 1 – control (without chemical application)

2 – P₁₂₀ + herbicides + fungicides

3 – P₁₂₀ N₄₅ + herbicides + fungicides

Table 2. Wheat yields (t/ha) with different methods of soil cultivation and chemical application in the Southern Forest-Steppe Zone of Omsk Region (1989-93).

Tillage	Wheat after fallow		Wheat after maize	
	1*	2*	1*	3*
Plow 20-22 cm	2.31	3.11	2.19	2.86
Combined subsoiling tillage	2.01	3.33	1.94	2.99
Subsoiling 10-12 cm	1.95	3.26	1.96	2.87
Minimum-zero tillage	1.89	3.08	1.65	2.67

* 1 – control (without chemical application)

2 – P₆₀ + herbicides + fungicides + CCC

3 – P₄₅ N₄₅ + herbicides + fungicides + CCC

Agrolandscape Agriculture and Forestry Management as the Basis of Sustainable Grain Production in the Steppes of Eurasia

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A vast area of black soils extends across the steppes of the Eurasian Region from Voronezh to Barnaul in Russia, and from Uralsk to Pavlodar in Kazakstan. Black soils occupy more than 90 mln ha including 42 mln ha that were plowed during the time of virgin land cultivation, among them 25 mln ha in Kazakstan. Cultivation of virgin land was necessary due to the lack of food in general and bread in particular.

In analyzing grain production development in Kazakstan during the last 50 years, we can single out certain broad agro-economic periods. Before the development of virgin and marginal lands (1946-1954), the sown area comprised only 7 mln ha, yields were 0.56 t/ha, total grain production

was 3.9 mln t, and the State received only 1.7 mln t (Table 1).

In the second decade (1954-64) of the development of virgin and marginal lands and research on anti erosion measures, the sown areas expanded up to 24.6 mln ha, yield potential grew to 0.7 t/ha and total grain production increased to 17.2 mln t, of which 7.7 mln t were delivered to the State.

However, mass plowing of large areas of land, especially those with soils of light mechanical composition, resulted in wind erosion. At that time it became necessary to develop anti erosion measures. Since 1959, a group of researchers at the Institute of Cereal Production headed by

academician A.I. Baraev worked out and implemented a comprehensive program for protecting soil against wind erosion which resulted in a soil conservation farming system. In the next decade (1965-1975) using this system on an area of 15.3 mln ha the yield increased to 0.89 t/ha, and total production, to 21.1 mln t. The State received 12.2 mln t each year.

With the full utilization of soil conservation technologies on 22.2 mln ha, average grain production rose to 24 mln t in 1976-1985. This period (and up to 1990) is characterized by intensification of grain production due to application of fertilizers and plant protection chemicals. Intensive technology was applied to 5-6 mln ha every year, which increased yield to 1 t/ha, while total grain production remained at 24 mln t.

The 1991-96 period should be considered from the following points of view: beginning of intensification of grain production up to the year 1992, loss of interest in research and agricultural production, deep economic crisis and catastrophic decrease in chemical application in the last three years. Cereal yields declined to 0.65 t/ha. The crop rotation system and seed production are not operating at present. Primitive technology is practiced to cultivate fallow fields, snow retention

Table 1. Wheat area, yield and total grain production in Kazakstan during the last 50 years.

Agro-economic period	Sown area (mln ha)	Soil protection tillage (mln ha)	Yield (t/ha)	Yield gains (t/ha)	Total grain prod-n (mln t)	Prod-n gains (mln t)	Procurement
Before development of virgin land: 1946-54	7.0	0	0.56	-	3.9	-	1.7
After development of virgin land: 1954-64	24.6	6.9	0.70	0.14	17.2	13.3	7.7
At development of soil conservation farming by periods:							
1965-1975	23.8	15.3	0.89	0.19	21.2	4.0	12.2
1976-1985	25.3	22.0	0.96	0.07	24.3	3.1	14.4
Intensification period: 1986-90	24.1	22.6	1.00	0.06	24.1	-0.2	10.5
Intensification decline: 1991-93	22.2	22.0	0.94	-0.08	21.7	-2.4	7.6
1994	18.9	8.7	0.79	-0.15	16.4	-5.3	4.1
1995	18.9*	4.6	0.50	-0.29	9.5	-6.9	0.8
1996	17.2	5.1	0.65	0.15	11.2	1.7	-
Average for 1994-96	18.3	6.1	0.65	-0.29	12.4	-9.3	-

is not applied and plowing in fall is done on one third of the total area. Fertilizers are not applied on cereals. Chemical control of weeds, pests and diseases is used minimally. Equipment is worn out, and fuel and lubricants are in short supply. Weeds are spreading, especially such as sagebrush, sowthistle, wild oats, wheat-grass, sedge, Russian thistle and bristlegass. Figure 1 shows the changes in weed populations, which increased due to diminishing herbicide application.

The extensive use of arable lands during the last 40 years has resulted in a 5-30% decrease in the humus content in the soil. The main farming principle has not been followed for decades, that is, returning nutrients to soils. As the result of water and wind erosion, decrease in humus content in soils, violation of technological methods, lack of chemicals, grain production in Kazakhstan is about to break down (Figures 2 and 3).

According to the theory of fluctuation of the earth and the humidity of the northern hemisphere, connected with periods of sun spot activity, drought incidence began rising in the late 1980s and will continue rising till 2030. This means rainfall may decrease, though during certain periods there will be humid years (Figure 4). The whole system of farming and grain production, in

particular, must be adapted to these unfavorable conditions. Agricultural science has the mechanism to adapt wheat production to possible climatic changes (Table 2).

A strategy for achieving sustainable grain production in the Republic was developed by the Kazak Academy of Agricultural Sciences. The Cabinet of Ministers of Kazakhstan approved "A

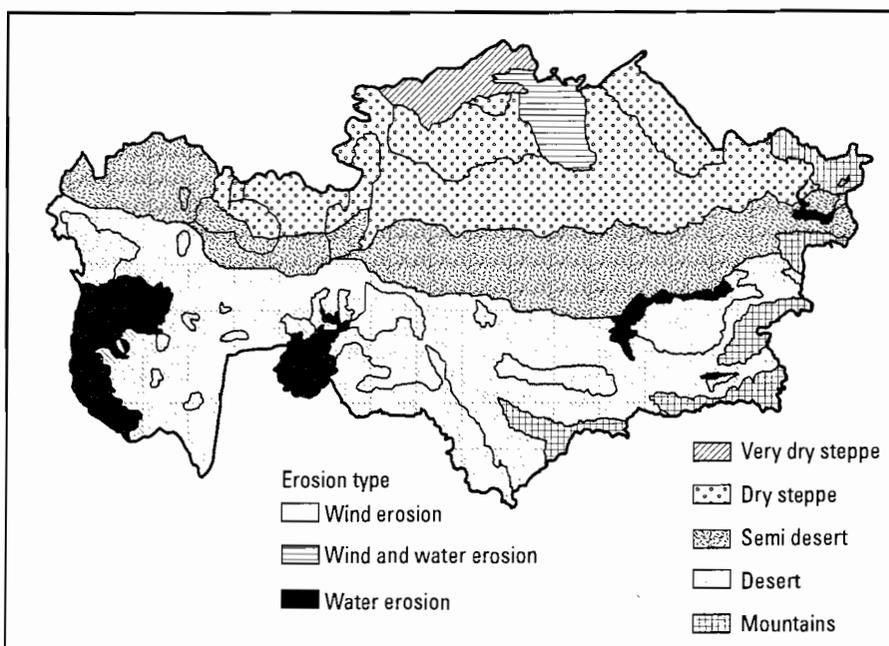


Figure 2. Soil erosion in Kazakhstan.

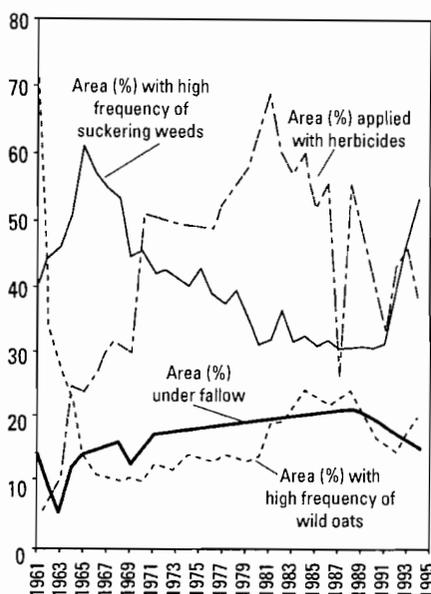


Figure 1. Utilization of fallow, application of herbicides and distribution of weed on cereal in Northern Kazakhstan, 1961-1994.

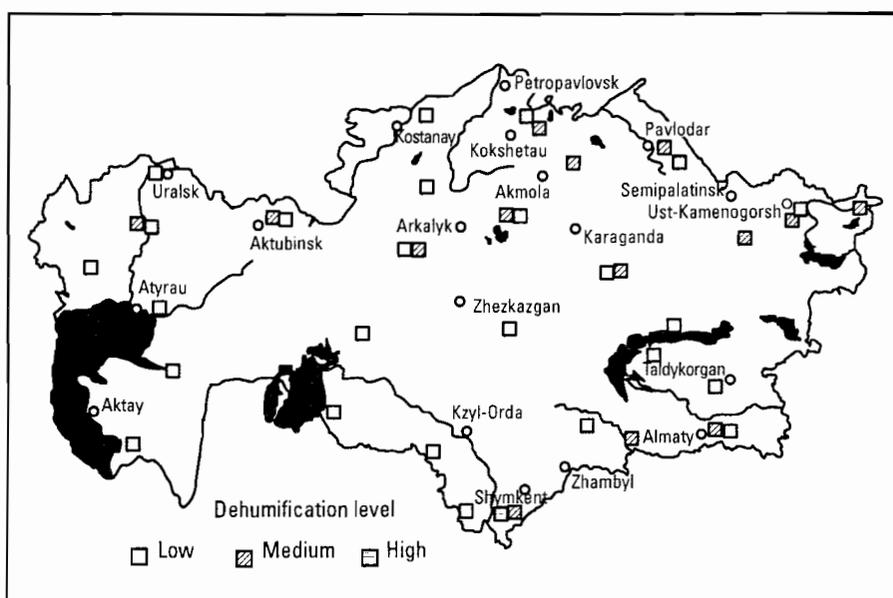


Figure 3. Soil dehumification in Kazakhstan.

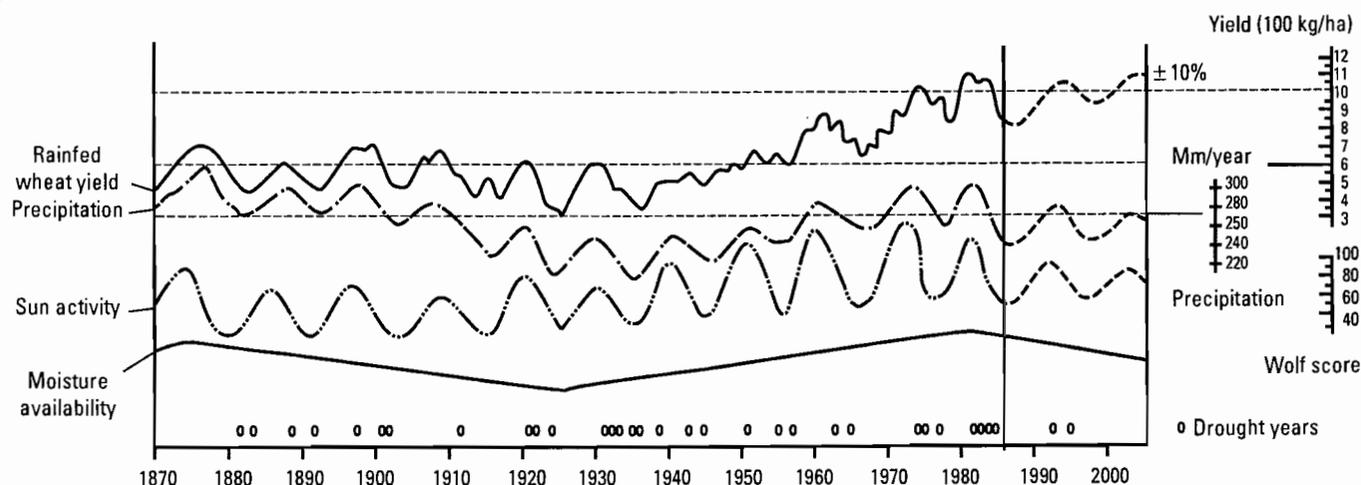


Figure 4. Variation in precipitation and wheat yield in Kazakhstan (moving 5-year means).

Table 2. Administrative and economic methods for adapting wheat production.

Informing farmers through mass media (newspaper "Eco", meteorological and ecological brochures, publication of seasonal bulletin on weather forecast, printing colorful booklets, explaining the essence of problems of climate change in accordance with the Framework Convention of UN)	Information – constant
Establishment of regional genetic resources centers for winter and spring wheat in Kazakhstan (Viliams Kazak Research Institute of Farming is a South Eastern center, A.I. Baraev Kazak Research Institute of Cereals Production is a Northern center)	The cost of research on genetic resources conservation in 1997 was 1.2 million tenge.
Storing extra seed stocks in years with favorable weather conditions to sow in dry years.	Total seed requirement is 2.8 million tons per year. 40% of extra stocks is 1.2 million tons. The cost is \$13.8 million.
Establishment of regional consultative service centers for farmers and peasant holdings to provide them with information about available seeds of varieties with variable maturity range.	Paid services on contract basis.
Analysis and distribution of results of long term seasonal meteorological forecasts to define the area of snow retention.	In winters with high precipitation the snow retention areas are reduced by 2.5-3 mln ha.
Medium and long term loans to buy equipment, seed of new varieties, fuel, lubricants and pesticides.	Seed production support - \$68.8 million. Support of producers in using priority technologies of crop growing: a) means of plant protection, b) mineral fertilizers – \$11.8 million.
Development of legislation considering economic changes in Kazakhstan's farm sector.	Permanent consultations.
Holding local scientific and practical workshops on how to observe agrobiological activities on adaptation.	The approximate level of purchasing prices for wheat is \$120-180 per ton.
Legislation on purchasing prices for grain both for domestic consumption and for exports.	Financed from guaranteed state budget.
Developing forecasts for pest and disease distribution during the growing season in order to plan pesticide purchase and application.	2 mln tons are necessary at an approximate cost of \$115 per ton, total is \$230 million.
Establishment of extra stocks of food in favorable years to compensate for the negative effects on population's diet in dry years.	Yield increases from 1.03 to 1.42 t/ha due to intensification. The cost of production of one ton of grain is \$115.1 Net income is \$56.6 per ha.
Cultivation of cereals in the regions with more favorable soil and climatic conditions using high input technologies as specified by the Conceptual Program of Agricultural Development.	Restoration and development of forests in 1996-2005 will constitute 595,000 hectares. The cost of planting one ha of forest is \$285, total expenses will be \$229 million.
Land reclamation and development of landscape projects to improve non-productive land in arid and semiarid zones.	

Conceptual Program of Agricultural Development until the Year 2000" that laid the basis for a new federal farm policy for the coming years. It regards the options of effective placement and structure of areas sown to the main agricultural crops by zones considering bioclimatic potential and economic demand.

The strategy included a gradual reduction of the cultivated area at the expense of extermination lands with low productivity from rotation, and preservation of total grain production (20-25 mln t) from the best lands in the grain belt of Kazakstan (Table 3). Production will be maintained due to three main intensification factors: application of mineral fertilizers, release of new varieties, and application of research-based soil and water conservation technologies.

Research institutions in Kazakstan have proven many times the important role of black fertilized fallow fields with a windbreak crop as the main agronomic method of moisture conservation and drought tolerance. With diminishing moisture, the proportion of black fallow in crop rotations should increase. In the future the adaptation of grain producing farms to the new conditions will be more favorable in 3 field and 4 field crop rotations with the fallow area reaching 25-33% (Figure 5).

On the vast arable lands of Kazakstan it is necessary to change from the soil conservation system of farming to adaptive and landscape system with contour organization of the fields. Soil conservation technologies are successfully applied

in Ukraine and Northern Caucasus. Academician B.I. Kiriushin (1995) published a book *The Methods of Development of Adaptive Landscape Farming Systems and Technologies of Crop Cultivation* in Moscow. The landscape and ecological division of the territory was implemented by scientists of the Russian Academy of Agricultural Science and the All-Russian Institute of Agricultural Aerogeodesic Research. It was intended for land monitoring and

evaluation, prognosis and control of land quality with the final objective of preserving and making rational use of it.

For the first time a comprehensive agricultural landscape project was developed by the A.I. Baraev Kazak Institute of Cereal Production and "Akmolagiprozem" targeting land use on the Institute's experimental farm (Figure 6). Its author is Dr. N.K. Azarov (1993).

Table 3. Wheat area, yield, total production and grain balance for different production development options.

Options	Sown areas (mln ha)	Yield (t/ha)	Prod-n (mln t)	Seeds	Food	Payment to farmers	Forage	Insurance stocks	Export reserve
Current situation	22.7	0.92	20.9	3.0	3.0	1.0	6.0	2.0	5.0
Excluding from production areas with yields of:									
Less than 0.5 t/ha	18.3	1.42	26.0	2.8	3.4	1.1	7.5	2.1	9.1
Less than 0.6 t/ha	16.3	1.49	24.2	2.4	3.4	1.2	7.5	2.0	7.7
Less than 0.7 t/ha	13.1	1.62	21.2	2.0	3.4	1.3	7.5	2.1	4.9
Less than 0.6-0.7 t/ha depending on the region	17.0	1.44	24.5	2.6	3.4	1.3	7.5	2.1	7.6

Indices for yield gains, calculation of total grain production due to intensification factors and their economic evaluation are given in appendices 3.1-3.6 in "The Conceptual Program for Agricultural Development of Kazakstan for 1993-95 and up to 2000."

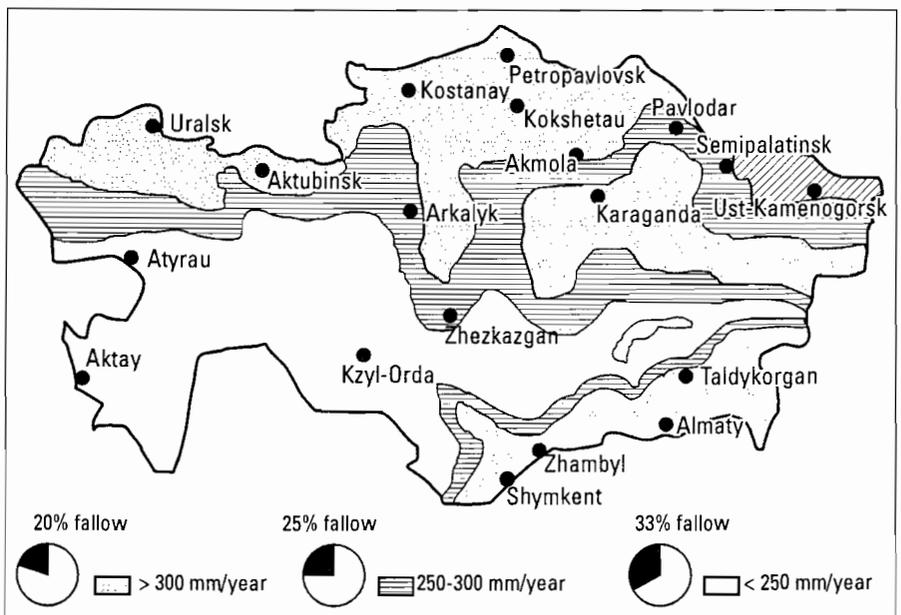


Figure 5. Annual precipitation and recommended share of fallow in crop rotation in Kazakstan.

While developing the large scale agricultural landscape project of Shortandy County and the Institute's experimental farm, land classification into landscapes was done based on the conditions for crop cultivation (Table 4).

Dr. N.K. Azarov's research on the Institute's experimental farm showed an opportunity to grow winter wheat in the best agricultural landscapes. Winter wheat yield during 4 years averaged 2.5 t/ha and that of spring wheat, 1.85 t/ha. In fields with less favorable conditions, winter and spring wheat yields were 0.84 t/ha and 1.64 t/ha, respectively.

For each agricultural landscape that includes fields with similar elements of topography, soil fertility, moisture content and yield capacity, certain soil-water-energy conservation technologies are recommended for cereal cultivation. In agrolandscapes with unfavorable conditions that are prone to wind and water erosion (slopes exposed to wind, water flows, ravines) soil conserving phyto-forest-ameliorative methods are used.

Joint projects of research and land use organizations such as Goskomzem make it possible to apply the agrolandscape methodology on farmers' fields. As a result of the large-scale agricultural

landscape classification of Northern Kazakhstan, there is an opportunity to expand the winter wheat area to 2-3 mln ha especially in the forest-steppe zone. The area under spring barley and rapeseed can be increased here as well because spring wheat is frequently damaged by the early fall frosts.

Conversion to the agrolandscape farming system will allow Kazakhstan's cereal belt to produce more than 20 mln t of grain per year. The export of a part of this grain to the world market, where a ton of superior quality wheat costs \$150-200, would not only pay for the credits and cover the expenses but would also economically strengthen the producer by introducing new scientific and technical achievements into the grain production industry.

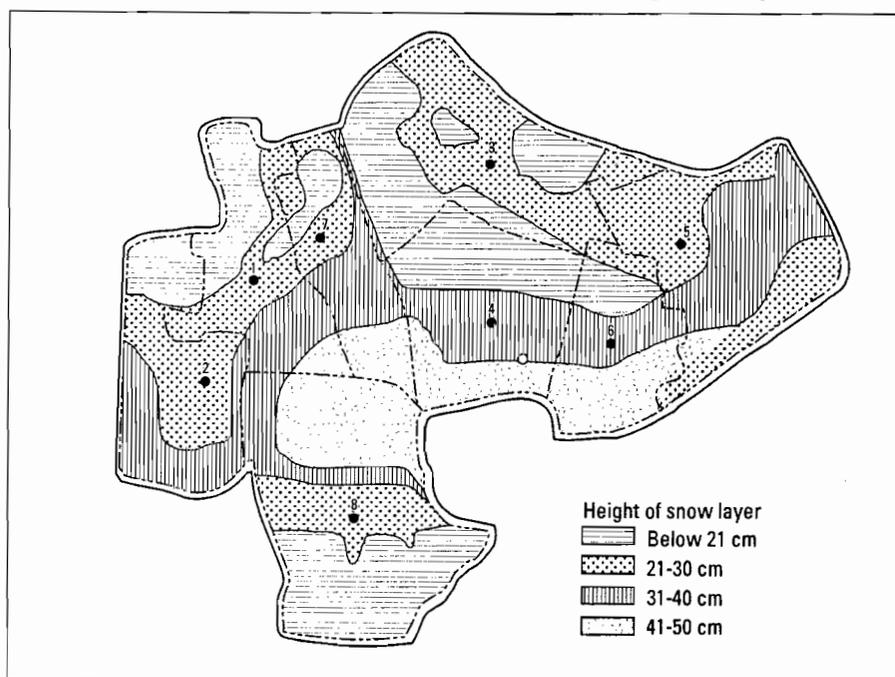


Figure 6. Distribution of winter precipitation in the fields of the experimental farm of Kazak Institute of Cereal Production.

Table 4. Classification of land in agricultural landscapes depending on conditions for cereal cultivation (A.I. Baraev Institute of Cereal Production, N.K. Azarov, calcareous black soils, Shortandy-1).

Agricultural landscape	Snow depth (cm)	Humus content (%)	Relief (degrees)	Yield (t/ha)	Conditions for cereal cultivation
1	>40	>4.5	<0.2	1.6-2.0	Good
2	31-40	4-4.5	0.2-0.5	1.2-1.8	Moderate
3	21-30	3-4	0.5-1.0	0.8-1.2	Poor
4	<21	<3	>1.0	<0.8	Very poor

Optimization of High Quality Wheat Production Zones in Kazakhstan

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For a long time, the area sown to cereals in Kazakhstan stabilized at the level of 24.0 mln ha and total grain production at the level of 22.0 mln t per year. Over the last several years, the situation in agriculture has deteriorated and has resulted in diminished area and production, which in 1996 were 17.6 mln ha and 12.0 mln t, respectively. Grain production is still the core of agricultural production, and the wheat share has remained more or less constant. Wheat grain produced in Kazakhstan is very valuable for the milling, baking and alcohol production industries, both domestic and foreign. Climatic conditions in the main grain producing regions (Kostanay, Kokshetau, Akmola, Pavlodar, Aktiubinsk, West Kazakhstan) favor the formation of a good quality grain. About 80% of wheat area and production is concentrated in these regions, notably spring wheat, which comprises 94% of total wheat production.

Grain yield and quality vary considerably depending on the year and region. Variation is determined by soil fertility, amount and timing of precipitation, air temperature (total and distribution by growth stages), variety, production technology, harvesting methods, after harvest processing, and storage. It is very important to study the influence of

natural and anthropogenic production factors on wheat yield and quality to determine the optimal zones for producing superior quality wheat. This research would result in a better definition of the best zones for wheat production. Similar research on optimal distribution of durum wheat in Canada based only on the yield was very important to enhance grain production in that country (Campbell, 1988). In the USA environmental conditions were given high priority while defining the regions for producing different quality types of American wheat such as red hard, white hard, and white soft.

We also understand the need to improve production zones. Analyses based on yield and quality data from the State Grain Board system (the state organization which buys the grain) have been carried out (West Kazakhstan Agricultural Institute, 1995; A.I. Baraev Kazak Institute of Cereal Production, 1995; V.R. Viliams Kazak Institute of Farming, 1995). However, data from the State Grain Board have limited value for such analyses for the following reasons:

- 1) quality evaluation is based on grain and gluten quality but not on the final product: flour and bread;
- 2) there is no information on varieties and seed source (not possible to estimate the choice of variety for the specific zone);

- 3) due to the lack of some grain classes, the data are not adjusted according to agronomic conditions;
- 4) dubious reliability of data due to administrative and economic contradictions in payment between producers and the Grain Board.

The objective of this research was determined by the producer's demand: to define the best zones for wheat production which would provide sustainable yields of high quality grain meeting the requirements of world standards for home use and export.

The data selected for the analysis had to be uniform, retrospective in nature (episodic and long-term), compatible, and reliable (Table 1). Considering these requirements, the State Variety Testing Commission seems to be the most appropriate source for the information needed. These data are less dependent on administrative and economic factors and were obtained from released varieties that are commercially grown across the country. This retrospective long-term information can be grouped by years, by technology of cultivation within certain zones and by specific testing sites. A uniform approach was used to collect the data according to state standards.

The data used in the analysis were collected during the last 23 years from 67 variety testing sites (Table 2). There were 12 quality parameters characterizing grain, gluten, flour, dough and bread coupled with yield data.

Statistical methods used for selecting quality and yield.

Numerous grain quality parameters cannot be reduced to a single quantitative index. Different statistical approaches are used to compare the quality of wheat genotypes. Considering that all parameters are equally important for making a decision on a variety release, none of them can be

excluded from this comparison. We have developed an algorithm for ranking varieties by quality and yield. Transforming primary data into simple classes according to our classification is the basis of the algorithm (Table 3).

Table 3 summarizes all the data and divides them into four quality classes: the 1st class - all grain, flour, dough and loaf quality parameters have maximum favorable values, the 4th class - the corresponding parameters match the quality of valuable wheat and lower; the 2nd and the 3rd classes have quality parameters intermediate between

strong and valuable wheat quality type. This table shows the whole range of variability for each quality trait. That is why each value of a quality parameter has its own position according to its class. In accordance with this classification all the data on varieties are transformed for each trait.

The data allow identifying the class of grain quality and yield produced in a particular region as well as stability across years. The frequency of each quality and yield class is the main criterion of the model describing variability across years and traits. The combination of classes and frequency liberates the model from the limits connected with the genetic nature of the varieties used.

Table 1. Data selection criteria for analyzing regional differences in wheat quality and yield.

Requirements	State Systems		
	State Grain Board	Variety Testing Commission	Research Institutes
Reference for quality testing	GOST - State Standard	Methods of s., 1988 Variety Testing Commission	None
Quality parameters tested	Test weight, moisture content, vitreousness, Protein content, gluten content gluten quality (IDK-1)	Test weight, moisture content, vitreousness, Protein content, gluten content, gluten quality (IDK-1) elasticity P, extensibility L, P/L, gluten strength, valorimeter value, loaf volume, general loaf score	Parameters are not specified and depend on the objective of breeding programs
Uniformity of data:	Yes - statistical data		periodic
By years	Yes - statistical data		
By regions	By administrative regions	By crop testing sites	episodic
By varieties	no	Very comprehensive set of data since 1981	Under special programs
By seed source	no	Uniform from breeders with obligatory identification	
By agronomic conditions	no	State Variety Testing Commission methodology - Uniform and observed at all testing sites	Within the limits of particular experiments and research programs
Reliability	Contradictory, connected with economic categories of payment between producers and the board	High, connected with arbitrary functions of State Variety Testing Commission system	

Another important methodological detail is utilization of long-term check varieties in classifying the environment. Variety Saratovskaya 29 was used as a long-term check because it was well represented in all these years (1971-1995) across all 56 cereal variety testing stations. This variety with superior (strong)

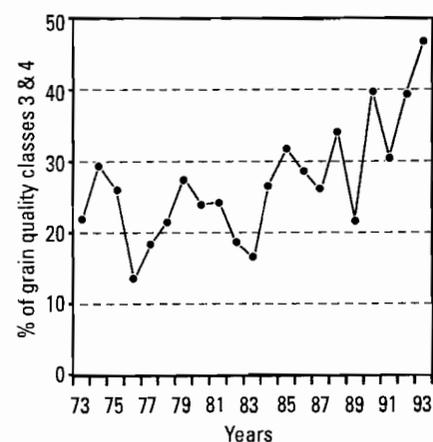


Figure 1. Average frequency of wheat grain quality classes 3 & 4 across variety testing sites in Kazakhstan.

genetically determined quality has morphological and biochemical (protein) markers that allow easy identification.

Classification of environments by wheat grain quality. The general dynamics of variability in quality across years is shown in Figure 1. In 15 out of 22 years, quality classes 3 and 4 did not exceed 30% of all observations. This means that for 15 years, high quality grain was formed in 70 out of 100 cases. In the remaining 7 years, this percentage varies from 32 to 48. Thus, high quality grain was obtained in more than 50 cases out of 100.

In the most important areas, frequency of classes 1 and 2 is 70% or higher. A more detailed study of the areas with the frequency of classes 1 and 2 between 50 and 70% was conducted using released bread wheat varieties currently in use.

Variety testing stations and the corresponding production areas are divided into three groups:

- 1) homogeneous for grain quality based on data for Saratovskaya 29 and other released varieties;
- 2) improved grain quality due to released varieties;
- 3) inferior grain quality due to released varieties.

In testing sites or stations that have limited quality characteristics, special attention is given to testing new varieties to solve this problem.

Table 2. Geographic locations of the state variety testing sites/stations, long-term yield and grain quality of reference variety and released varieties.

#	Name of site/station	Yield (t/ha)		Frequency (%) of quality class 1+2		Geographic location	
		Sarat. 29	Released varieties	Saratov29	Released varieties	longitude	latitude
Akmola region							
1	Balkashinskiy	2.53	2.89	66	60	68°36'	52°34'
2	Shortandinskiy	2.43	2.72	65	57	70°00'	51°37'
3	Tselinogradskiy	1.46	1.49	68	71	71°20'	51°29'
4	Krasnoznamennyi	1.80	1.77	80	74	69°34'	51°04'
Aktjubinsk region							
5	Alginskiy	1.40	1.66	70	45	57°21'	49°51'
6	Komsomolskiy	0.89	1.78	78	43	60°32'	50°27'
7	Martukskiy	1.70	2.08	76	49	56°37'	50°42'
8	Khobdinskiy	0.88	1.25	71	35	55°20'	50°06'
9	Mugadzarskiy	0.62	0.42	71	38	58°40'	49°11'
10	Ilysiy multicrop	-	2.51	-	39	76°54'	43°52'
11	Ilysiy irrigated	-	4.52	-	29	76°54'	43°57'
12	Ilysiy rainfed	-	1.24	-	67	76°54'	43°57'
Eastern-Kazakstan region							
13	Zyryanovskiy	-	2.45	-	36	84°20'	49°42'
14	Shemonaikhinskiy	-	2.15	-	55	82°54'	50°40'
15	Tavricheskiy	2.02	1.60	79	65	82°00'	50°08'
16	Kurchumskiy	3.55	3.51	64	29	83°36'	48°32'
Western-Kazakstan region							
17	Burlinskiy	-	1.34	-	58	52°42'	51°27'
18	Djambaitinskiy	-	1.86	-	63	52°26'	50°16'
19	Zelenovskiy	-	1.47	-	56	50°40'	51°08'
20	Chapaevskiy	-	0.73	-	58		
Zhezkazgan region							
21	Zhana-Arkinskiy	0.96	1.09	72	54	72°51'	48°36'
Karagandy region							
22	Oskarovskiy	1.90	2.20	81	61	72°33'	50°33'
23	Karkaralinskiy	0.98	1.41	83	53	75°23'	49°21'
Kokshetau region							
24	Krasnoarmeiskiy	2.03	1.68	64	59	69°16'	53°38'
25	Kokshetauskiy	1.46	1.40	69	67	69°12'	53°14'
26	Ruzaevskiy	2.07	1.80	71	63	67°00'	52°48'
27	Kzylytuskii	1.74	1.91	70	66	72°16'	53°38'
28	Kazanskiy	2.58	2.31	56	59	68°10'	53°16'
29	Arykbalykskiy	2.18	2.15	63	54	68°06'	52°58'
30	Shuchinskiy	2.04	2.20	59	52		
Kostanay region							
31	Uzunkolskiy	2.27	2.14	67	65		
32	Uritskiy	2.63	1.97	63	51	65°22'	53°16'
33	Fedorovskiy	2.48	3.23	77	55	62°45'	53°38'
34	Karabalykskiy	2.27	2.43	58	63	62°23'	53°27'
35	Kostanaiskiy	1.52	1.99	73	63	64°11'	52°19'
36	Kamyshinskiy	1.84	2.43	20	42	61°50'	51°54'
37	Semiozernyi	1.61	1.62	67	64	64°12'	52°16'
Pavlodar region							
38	Irtyskiy	1.15	1.34	56	71	75°22'	53°21'
39	Urlyutyubskiy	1.13	1.38	62	65	75°02'	53°43'
40	Pavlodarskiy	0.78	0.71	87	83	77°00'	52°16'
41	Ermakovskiy	0.85	0.85	81	80	76°50'	52°00'
42	Mayskiy	0.53	-	94	-	78°12'	50°53'

Table 2. (continued)

Northern-Kazakstan region							
43	Suvorovskiy	2.56	1.93	67	45	70°24'	54°40'
44	Leninskiy	2.03	2.07	70	66	68°38'	54°17'
45	Presnovskiy	2.79	2.29	71	62	67°08'	54°38'
46	Oktyabrskiy	2.05	1.97	68	69	67°24'	53°54'
Semipalatinsk region							
47	Novo-Pokrovskiy	1.32	1.02	69	63	81°00'	50°40'
48	Kokpektinskiy	2.13	2.28	69	55	82°20'	49°05'
49	Novo-Shulbinskiy	2.16	2.26	71	62	81°12'	50°30'
50	Charskiy	1.52	1.62	76	76	81°00'	49°30'
51	Zharminskiy	2.80	2.86	58	72		
52	Urdjarskiy	1.86	1.63	70	69	81°35'	47°19'
Torgay region							
53	Oktyabrskiy	1.85	1.73	67	55	65°50'	52°06'
54	Zhaksynskiy	1.94	2.44	83	71	67°12'	51°57'
55	Derzhavinskiy	1.51	1.73	80	76	66°18'	51°35'
56	Torgaiskiy	2.25	2.04	61	57	63°27'	49°40'
57	Arkalykskiy	1.55	1.80	89	92		
Taldy-Korgan region							
58	Gvardeyskiy		2.49		37	78°33'	44°30'
59	Sarkandskiy		3.02		63	79°50'	45°27'
60	Taldy-Korganskiy		2.95		33	78°19'	45°00'
61	Kerboulakskiy		1.24		83	77°53'	44°03'
62	Alakulskiy		4.08		39	80°53'	46°16'
Southern-Kazakstan region							
63	Sarygashskiy		0.95		45	69°14'	41°32'
64	Georgievskiy		2.57		53	74°42'	43°09'
65	Kelesskiy		1.16		79		
Zhambul region							
66	Djuvalinskiy		2.20		42	75°00'	43°40'
67	Krasnogorsliy		2.00		33	69°14'	41°32'

Table 3. Classification of hard bread wheat to classify the regions of production.

Quality and yield parameters	Range of variability according to the requirements of wheat quality types:			
	Strong (superior) quality		Valuable quality	
	1 class	2 class	3 class	4 class
Test weight, g/l	> 800	799-750	749-730	< 729
Vitreousness, %	> 70	69-60	59-50	< 49
Protein content, %	> 16.0	115.9-14.0	13.9-13.0	< 12.9
Gluten content, %	> 36.1	36.0-32.0	31.9-28.0	< 27.9
Gluten quality, IDK score	45-79	75-80	80->85	0 - 40 85 - 120
Dough elasticity, P	> 100	99-80	79-70	< 69
Elasticity/extensibility, P/L	0.8-1.2	0.7->0.8 1.3-2.0	0.5->0.7 2.1-2.2	< 0.5
Gluten strength, alveograph value	> 450	449-280	279-260	< 259 >2.2
Dough resistance to mixing	< 30	31-60	61-80	> 81
Valorimeter value	> 80	79-70	69-55	< 54
Loaf volume, ml	>1300	1290-1200	1190-1000	< 990
General baking score	5.0	4.9-4.5	4.4-4.0	< 3.9
Yield, t/ha	> 3.0	2.9-1.2	1.2-0.8	< 0.8

According to the results of statistical data analyses of both the reference variety (Saratovskaya 29) and the released varieties, the state variety testing sites/stations are divided into:

1. "Poor quality" environments with class 3 and 4 frequency (the worst quality), as observed on the reference and released varieties, exceeding 30%. These are the Southern and Eastern testing sites/stations: Iliyskiy irrigated, Krasnogorskiy, Taldy-Korganskiy, Zyrianovskiy, Gvardeyskiy, Djuvalinskiy, Kurchumskiy, Iliyskiy multi-crop, Chapaevskiy, Komsomolskiy, Georgievskiy, Shemonaikhinskiy. The same group contains Tschuchinskiy, Aribakalskiy, Urtskiy, and Turgayskiy, Shortandinskiy, which have the frequency of classes 3 and 4 higher than 30%.
2. "Good quality" environments with minimum frequency of quality classes 3 and 4 (worst quality) as observed on reference and released varieties. The following testing sites/stations and corresponding regions have high and stable quality performance: Aralykskiy, Pavlodarskiy, Ermakovskiy, Derzhavinskiy, Krasnoznamenitskiy, Charskiy, Zhaksinskiy, Kokshetauskiy, Akmolinskiy, Tavricheskiy, Kziltuskiy, Urdjarskiy, Zharminskiy, Kostanaiskiy, Uzunkolskiy, Leninskiy, Novo-Pokrovskiy.

3. "Variable quality" testing sites/stations for which the breeding for stability of grain quality is necessary: Leninskiy, Novopokrovskiy, Osakarovskiy, Semiozernyi, Ruzaevskiy, Novoshulbinskiy, Presnovskiy, Irtyskashinskiy, Karabalikskiy, Sarkandskiy, Oktyabrskiy, Krasnoarmeyskiy, Karkaralinskiy, Zhana-Arkinskiy, Kokpektinskiy, Oktiabrskiy (Torgay region), Maktukskiy, Alginskiy, Suvorovskiy, Mugajarskiy, Sariagashskiy, Khobdinskiy. These stations should be given special attention because they need new high quality and stable varieties.

Classification of environments based on yield. As a rule an average yield for several years is used to compare different wheat producing regions also taking into account the

coefficient of stability. The following state variety testing sites/stations are the poorest yielding as judged by the performance of variety Saratovskaya 29: Uliyanovskiy, Karagandy region, (0.43 t/ha), Mayskiy (0.53 t/ha), Mugajarskiy (0.62 t/ha), Pavlodarskiy (0.78 t/ha), Ermakovskiy (0.85 t/ha), Hobdinskiy (0.88 t/ha).

The following state variety testing stations are the most productive when comparing the data of the reference variety: Zharminskiy and Presnovskiy (2.80 and 2.79 t/ha), Urytskiy, Kazanskiy, Mamlutskiy, Suvorovskiy, Balkashinskiy (2.63-2.53 t/ha), Fedorovskiy and Shortandynskiy (2.48-2.43 t/ha). As can be seen from Table 4, the use of average yield for a set of varieties instead of one variety can change the ranking in both directions. To

characterize more adequately the yield potential of a certain location, a set of released varieties should be tested along with the reference variety.

The average parameter value alone does not reflect yield variability and stability in different years. To do this the frequency of yield class 3 (0.8-1.23 t/ha) and class 4 (<0.8 t/ha) was included into classification. The minimum and maximum yields in a particular environment are the additional trait to characterize a location. That is why the classification of environment is more acceptable when the following parameters are considered: minimum and maximum values over many years, frequency of classes 3 and 4 (the lowest yield) as a sustainability index. The analysis of the data on one variety for many years provides retrospective depth of research, and data on released assortment allows to specify the environment classification and optimize the localization of variety ecological niches.

Based on this analysis, state variety testing sites/stations are subdivided into three types:

1. Low-yielding (average yield less than 0.8 t/ha, with low minimum and maximum productivity and high frequency of classes 3 and 4). These are Mayskiy, Uliyanovskiy, Nurinskiy, Mugajarskiy, Pavlodarskiy, Saryagashskiy, Chapaevskiy, Ermakovskiy, Jana-Arkinskiy, Khobdinskiy, Novopokrovskiy, Karkaralinskiy;

Table 4. Classification of spring wheat production zones based on average yield (1973-1995).

Region and variety testing site/station	Average yield (t/ha)		Maximum yields across years	
	Saratovskaya 29	Set of varieties	(t/ha)	Variety
Akmola region				
1. Balkashinskiy	2.53	2.89	3.09.	Omskaya 19
2. Shortandinskiy	2.43	2.72	3.24	Kazakstanskaya 15
3. Krasnoznameniy	1.80	1.77	2.10	Tselinnaya Ubileynaya
4. Tselinogradskiy	1.46	1.49	1.95	Kazakstanskaya 15
Aktiubinsk region				
5. Alginskiy	1.40	1.66	1.70	Saratovskaya 42
6. Komsomolskiy	0.89	1.78	1.83	Saratovskaya 55
7. Martukskiy	1.70	2.08	2.12	Saratovskaya 55
8. Khobdinskiy	0.88	1.25	1.25	Saratovskaya 42
9. Mugajarskiy	0.62	0.48		
Kostanay region				
36. Uzunukolskiy	2.27	2.14	2.44	Kazakstanskaya 25
37. Uritskiy	2.63	1.97	2.57	Kazakstanskaya 19
38. Fedorovskiy	2.48	3.23	4.25	Omskaya 20
39. Karabalykskiy	2.27	2.43	3.51	Omskaya 20
			2.90	Kazakstanskaya 25
40. Kostanayskiy	1.52	1.99	2.27	Kazakstanskaya 19
			2.21	Omskaya 20
41. Kamyshinskiy	1.84	2.43	3.53	Omskaya 20
			3.01	Kazakstanskaya 19
42. Semiozernyi	1.61	1.62	2.02	Omskaya 20

2. Variable (do not meet the requirements of our classification, for example, minimum yield, the frequency of classes 3 and 4, the average yield in different combinations). There are locations within group 2 where the problems are solved by releasing new varieties. For such locations new genotypes with a higher yield capacity have been bred and these sites have good potential for hard wheat production. These are the following nine testing sites: Komsomolskiy, Kokshetauskiy, Tselinogradskiy, Alginskiy, Semiozerniy, Arkalykskiy, Kostanayskiy, Ruzaevskiy, Tchuchinskiy. As judged by the yield of the reference variety, some locations demonstrate stable average yield: Irtyshskiy, Urlutubinskiy, Charskiy, Derzhavinskiy, Urjarskiy, Kzyltusskiy, Krasnoznamennyi, Osakarovskiy. For the region being represented by Tavricheskiy testing site breeding for yield potential can result in increased average yield. For the regions represented by Oktiabrskiy and Enbekshildinskiy

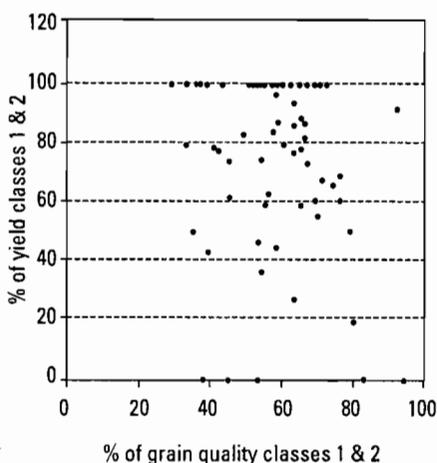


Figure 2. Distribution of variety testing sites in Kazakhstan according to yield and grain quality.

state variety testing sites breeding for both potential and stability is needed since the yield of the released varieties is even worse than the reference variety.

3. Locations that produce high, stable yields.

Figure 2 shows the distribution of the testing sites according to yield and quality. The locations within the 70 x 70 square are the most promising because they combine high quality and high yield potential in 70% of years. The respective production zones can be used for grain export. Locations beyond the 30 x 30 square represent the zones that must be excluded from grain production as non-profitable. All other locations should be considered for selection of the varieties best adapted to a particular region providing high yield and good quality.

Several issues for discussion. There are 38 varieties of spring bread wheat, 22 varieties of winter bread wheat, 9 varieties of spring durum wheat and 1 variety of winter durum wheat released in Kazakhstan. These varieties can provide basis for wheat production in Kazakhstan. According to the results of our research we reached the following conclusions.

1) For the regions which are not recommended for grain production due to low yield and poor quality, there is no need to invest money into breeding.

2) For grain producing regions where high quality grain yields are obtained, varieties should not be released but registered, i.e., legally recommended for cultivation in certain areas. Why? The varieties created for these areas compete with each other because their yield is similar. If some of them are preferred then certain valuable genotypes developed for these conditions could be lost. If varieties are recommended it will provide a choice for the producer based on market requirements because:

- All varieties have some disadvantages (poor resistance to stresses, diseases, pests, poor quality parameters, etc.). To correct these problems money is needed.
- Each variety has certain amount of seed in a particular year. The farmer chooses which seeds to buy, how much to pay independently of the country of origin and the producer of the seed.
- For these regions maintenance breeding should be carried out addressing first of all the conservation of the yield level and dealing with the drawbacks of the released varieties: pest and disease resistance, pre-harvest sprouting resistance, etc.

3) For "problematic" regions new, well adapted varieties should be bred.

These are the first results obtained for optimization of bread wheat production in Kazakhstan. However, since there is a huge network of state variety testing sites, we can expand the research and make our classification similar to CIMMYT's mega-environments.

Grain hardness. Grain production in Kazakhstan is historically oriented towards bread wheat. As the result of many years of breeding, spring bread wheat varieties have hard or medium hard grain. However, due to the lack of methodical and laboratory base to determine a grain hardness index, the genetic differentiation for hard and soft wheat is not clear. The importance of determining a hardness index is connected to the breeding strategy, the technology for milling and preparing flour blends, and optimization of production zones for specific classes of wheat varieties.

In the past decade, the Research Laboratory of Grain Marketing, USA (Manhattan, Kansas) and the Perten Instrument Company developed a method for determining hardness on single kernels that is widely used to evaluate wheat of different origins: USA, Canada, Australia, Morocco and others.

The Central Laboratory of State Bread Quality Inspection of Kazakhstan gave us the opportunity to work with the device Perten Instruments SKCS 4100 (Single Kernel Characterization System). The objective of the study was to classify Kazak varieties for grain hardness and relate it to their end-use as well as to use this data to calibrate the NIR-analyzer.

The results of the analysis showed that most of them belong to medium hard and hard type (Table 5). The grain of the variety Kazakstanskaya Rannespelaya is very hard exceeding the limit of 120 units on the device SCKS 4100. The designers of this device are asked to expand the range of the hardness index for Kazak wheats up to 140 units.

The range of variability for kernel hardness for released and new varieties of winter bread wheat is shown in Table 6. Soft varieties and mixtures were identified. These are mainly samples from the fields in Almaty, Zhambyl and Shimkent

regions. They are represented by varieties Botagoz (with a soft-hard ratio of 46-54), Batyr (98-11), Kazakstanskaya 10 (58-42), Koksu (43-57 and 28-72), Eritrospermum 260 (35-75), Arman (31-69), Zhetysu (32-68), Sapaly (43-57), Yuzhnaya 12 (32-68). It is difficult to explain the reasons for such diversity. Grain hardness and the ratio between soft and hard kernels depend both on the purity of the original variety and growing conditions.

Table 5. Quality parameters of spring bread wheat varieties released in Kazakhstan.

Variety	1000 kernel weight (g) min-max	Vitreousness (%) min-max	Hardness index	Number of kernels	
				Soft min-max	Hard min-max
Akmola 2	29.3-38.8	60-87	66-76	2-5	95-98
Altayskaya 50	31.2-40.9	60-93	63-72	5-8	92-95
Vera	39.2	41	63	5	95
Druzhina	26.4-31.1	10-38	51-70	-	-
Intensivnaya	34.2-35.2	56-56	64-69	6	94
Irtyshtanka	34.1-39.6	26-85	54-90	12	88
Kazakstanskaya 3	36.6-38.0	32-39	58-65	7	93
Kazakstanskaya 4	40.3-44.9	58-60	64-69	11	89
Kazakstanskaya 10	34.8-40.0	52-59	60-65	11	89
Kazakstanskaya 15	28.4-36.9	50-89	56-88	2-11	89-98
Kazakstanskaya 19	34.0-40.3	45-95	65-89	8	92
Kazakstanskaya 25	30.4-34.2	39-93	66-89	4	96
Kaz. Rannespelaya	31.2-37.6	43-96	71-110	1-7	93-99
Karabalijskaya 90	33.9-41.7	30-90	61-81	10	90
Karagandynskaya 93	34.3	42	62	5	95
Kenzhegaly	29.5-35.9	65-92	64-78	5-6	94-95
Kutulukskaya	33.2-37.3	35-45	56-72	-	-
Lutestcenc 32	33.9-43.5	52-90	58-88	10-15	85-90
Lutestcenc 521	36.6	52	61	-	-
Omskaya 18	31.5-42.1	17-92	58-90	11	89
Omskaya 19	27.4-38.9	25-95	60-81	2-19	81-98
Pamiat 47	37.5	57	72	2	98
Saratovskaya 29	28.3-40.4	30-98	57-102	7-21	79-93
Saratovskaya 42	31.8-40.4	45-96	68-98	4	96
Saratovskaya 55	26.6-33.6	26-98	68-103	8	92
Saratovskaya 58	37.4	49	84	-	-
Skala	28.6	39	67	-	-
Tselinnaya 21	33.1	59	76	-	-
Tselinnaya 24	25.6-32.7	59-69	65-80	1	99
Tselinnaya 26	29.9-38.4	5-49	51-78	-	-
Tselinaya Yubileinaya	28.0-37.6	25-91	60-86	4-27	73-96
Tselinnaya 3c	29.6-38.3	53-73	65-87	3-10	90-97
Eritrospermum 35	32.0-34.8	27-92	68-89	-	-
Eritrospermum 841	31.4-38.0	47-56	54-66	16-21	79-94

Grain hardness should be one of the objectives of winter wheat improvement in Kazakhstan, as well as one of the components of wheat grain classification as it used to be under the Soviet system. Unfortunately the institutions involved in wheat breeding and testing do not have the appropriate equipment which is an obstacle for the first stage of wheat quality improvement – developing and improving varieties. This is

especially important for winter wheat varieties characterized by high variation in grain hardness: from hard to medium and soft type.

Suggestions for collaboration with CIMMYT:

1. Definition of mega-environments for spring wheat production in Kazakhstan; identification of testing sites based on yields and grain quality.

2. A cooperative program for improvement of winter wheat quality including evaluation of protein content and sedimentation value as well as grain hardness as a criterion for wheat classification according to end-use (bread, confectionery, alcohol, etc.).

Table 6. Quality of winter bread wheat varieties released in Kazakhstan, 1996.

Variety	1000 kernel weight (g) min-max	Vitreousness (%) min-max	Hardness index	Number of kernels	
				Soft min-max	Hard min-max
Bezostaya 1	26.2-48.6	30-98	49-71	4-41	59-96
Bogarnaya 1	26.0-38.8	28-98	54-75	5-21	79-95
Jetisu	25.9-46.9	13-98	48-73	8-32	68-92
Intensivnaya	32.2-35.2	56-69	67-69	31	69
Kazkhstanskaya 10	34.8-50.5	23-59	44-65	11-56	42-89
Karligash	39.9	38	52	-	-
Krasnovodopadskaya 210	39.8-42.7	59-72	66-80	-	-
Progress	39.2-49.5	40-43	38-63	13	87
Pamyat 47	44.6	60	66	-	-
Odesskaya 120	28.7-45.2	33-96	51-74	7-13	87-93
Oktyabrina 70	40.0-48.2	43-54	60-66	-	-
Mironovskaya 808	44.9	42	53	-	-
Spartanka	31.6-45.9	26-97	46-70	8-19	76-93
Steklovidnaya 24	27.3-51.4	14-96	56-74	4-28	72-96
Eritrospermum 350	40.0	42	56	-21	79
Yuzhnaya 12	31.4-51.3	25-68	53-68	22-32	68-78

Protecting Wheat from Pests, Diseases, and Weeds in Kazakhstan

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From the beginning of farming, mankind has had to control weeds, pests, and diseases. Wheat is not only our main agricultural product but it is also our hard currency and politics. The further increase of wheat production is our major agricultural objective. Crop protection is a very important component of wheat production. It is not a question of whether to protect a crop or not. The question is how to protect it better.

Currently the damage caused by pests, diseases, and weeds is more evident than in the past. The history of agriculture is also the history of the evolution of pests. Any effort by man to increase agricultural production results in improved conditions for diseases, pests, and weeds. Take, for instance, the sunni bug which previously lived on wild cereal species in the Caucasus and Southwest Asia. When the bug started to live on wheat, it became very aggressive and fertile and multiplied dramatically. Now in Kazakhstan measures have to be taken annually to control the sunni bug in the Western, Eastern, Southern, and Aktjubinsk regions. After bringing into cultivation the virgin lands of Northern Kazakhstan, the gray grain cutworm (*Apamea anceps*) propagated in enormous quantities and in 1957 destroyed 2.5 mln t of grain. Farmers remember the dramatic invasions of locust, marmots, mice, beet webworm and other pests, which left whole regions without grain and pastures.

Large-scale invasions of insects, mites and rodents as well as epidemics of different diseases are common at present. Only due to the scientific and technical progress achieved in the 20th century can we limit their development. In 1989-91 farmers had to apply chemical on 3-3.5 mln ha to protect against locusts. In 1996-97 just in Northern Kazakhstan such measures were applied on 1 mln ha. Before the development of virgin lands, farmers did not encounter many weed species such as wild oats. Some weed species became resistant to herbicides. Scientists have shown that the higher the yield the more efforts and inputs are needed to raise yields further. Proportionally the cost of crop protection measures increases. When yields double, the losses from pests triple or quadruple and the cost of protection increases 6-8 times. However, the costs of crop protection are normally compensated for by increased yield and financially compensated 2-10 times.

Recent technological changes have resulted in increased infection by smuts, rusts and septoria leaf blotch. In 1996 cereal yield losses from disease exceeded 20%. There is a dramatic increase in weed populations, with 60-70% of all fields having high levels of weed infestation. Weeds like Canada thistle, sow thistle, and green foxtail recently became very important. Wild oats has now spread over 6 mln ha and Russian suretsultan, over 2 mln ha. There is a

significant increase in populations of insects such as locusts, gray grain cutworm, sunni bug, Hessian fly and sawfly. For instance, during the past year, insect traps located on the experimental farm of the A.I. Baraev Kazak Institute of Cereal Production caught a number of pests; 68% of them belonged to different locust species. This indicates the change in adaptability of the pest, which is now able to overwinter directly in the fields.

There are 170 species of pests that damage cereals in Kazakhstan. However, 15-20 species cause major damage and substantial yield losses. Over the last years control of locusts has become very important. There are around 400 species of locusts in the country, though only 5-10 actually attack wheat, including some non-traditional species such as *Chorthippus albomarginatus*, *Aeropus sibiricus*, and *Dociostaurus kraussi*. If previously locusts migrated from virgin lands to the crop, now they complete their development cycle in wheat. The density of the locust population in Northern Kazakhstan sometimes reaches 150 insects per m², which completely destroys the crop. Based on the investigation of the locust's biological cycle, several highly effective insecticides were recommended. Unfortunately, deviation from wheat cropping technology (absence of pre-planting tillage, planting into wheat stubble) and improper pesticide application made it impossible to protect the crop against losses.

Gray grain cutworm (*Apamea anceps*) population has also increased. In some years the larvae of this insect are able to completely destroy the crop. The most favorable conditions for the development of this pest coincide with mass butterfly appearance during wheat heading. For instance in 1997 wheat planted on May 15 had 40 larvae per 100 tillers, wheat planted on May 25 had three, and wheat planted on June 5 had none. This tendency not always is taken into consideration when planning control measures. The population of gray grain cutworm follows a cyclic model of development, which depends on solar activity. Due to this it is relatively easy to predict the development and distribution of this pest as well as locusts using the models developed at the Institute.

The steppe zones of Kostanay, Kokshetau and Akmola regions suffer from increased population of Hessian fly (*Mayetiola destructor*). The last mass appearance of this pest was observed in 1978-81 when it destroyed 60-70% of tillers and grain losses reached 0.33 t/ha. The application of appropriate agronomic measures (crop rotation, isolation of wheat fields, pre-planting cultivation, late sowing dates) is essential for controlling the pest and coupled with recommended pesticides provides complete protection. Sawfly (*Cephus pygmaeus*), previously only distributed in the Western part of the country, has now spread into the Eastern Kazakstan region as well. Yield losses from this pest can reach 0.20-0.35 t/ha. Chemical control measures are not effective and agronomic measures are recommended as well as development of resistant varieties.

The sunni bug is a very dangerous pest that not only reduces yields, but also affects grain quality. The bug is spread over the western, southern, and southeastern parts of the country but not in Northern Kazakstan. The threshold population frequency, chemical and agronomic protection measures developed by the Institute allow to protect the crop. Experiments show that sunni bug does not always affect the quality of wheat especially in fields with low nitrogen supply.

Other insects damaging wheat production in Kazakstan are strip flea (*Phyllotreta vittula*), cereal flea (*Chaetocnema aridula*, *Ch. hortensis*) carabide (*Zabrus tenebrioides*), wheat thrips (*Haplothrips tritici*), leaf beetle (*Lema melanopus*), Swedish fly (*Oscinella pusilla*, *O. frit*), spring fly (*Phorbia seciris*), and wheat mite (*Steneotarsonemus panschini*). To control wheat pests, the Institute recommends a number of insecticides and acaricides such as Fastak, Sumi-Alpha, Carate, Desis, Fjury, Sherpa, and Bulldog as well as the methods of their application. Agronomic control methods should not be underestimated. For example, soil cultivation prior to sowing reduces the population of gray grain cutworm, Hessian fly, wheat bugs and other pests. In such cases there is no need to apply chemicals. In dry years the damage from some pests also decreases. Frequent application of chemicals results in the increase of the population.

Cultivation of varieties resistant to insects and mites is extremely important to regulate pest populations and decrease the application of chemicals, thereby reducing environmental pollution.

Despite this, utilization of genetic resistance has not been sufficiently explored up to now. Among the 85 varieties of spring wheat tested over the last few years in different regions of the country several were resistant to Swedish fly (Magistralnaya) and Hessian fly (Svetlana, Saratovskaya 40). Variety Isheevskaya was resistant to different fly species and variety Uiskaya was resistant to Swedish fly and sawfly. Some varieties combining tolerance to Swedish fly with high and stable yield were identified: Tselinnaya 26, Svetlana, Bezenchukskaya 182, Saratovskaya zolotistaya. These varieties could be damaged up to 54% but the yield loss would reach only 0.2-3.3%. The varieties most resistant to wheat thrips are Kazakstanskaya 4, Kazakstanskaya 21, Voronezhskaya 7, Zarnitsa Altaya which demonstrate yield losses of only 1.1-2.3%.

It is impossible to solve the problem only by breeding resistant varieties. In our opinion breeding should emphasize only resistance to those insects for which it is difficult to use other methods of protection or which require frequent chemical applications, such as cereal flies, sunni bug, gray grain cutworm and sawfly.

It is well known that part of the yield is lost due to diseases. The spread of diseases depends on the region of the country. In Northern Kazakstan the most important pathogens are septoria leaf blotch (*Septoria nodorum*), leaf rust (*Puccinia recondita*), *Helminthosporium* blotch (*Dreschlera bipolaris-sorokiniana* – *Helminthosporium sativum*, *Dreschlera repentis*), root rots (*Helminthosporium sativum*, *Fusarium* sp.) loose smut (*Ustilago tritici*), black point

(*Alternaria alternata*, *Helminthosporium sativum*). Winter wheat in Southern and Southeastern Kazakstan is damaged by common and dwarf bunt (*Tilletia caries*, *Tilletia controversa*) as well as *Septoria* spp.

Long-term experiments conducted at the Institute showed that the strategy and methodology of wheat protection against disease depend on the biology of pathogen, and the way it is transmitted and survives in nature. For instance, protection against seedborne diseases (smuts, *Septoria*, *Helminthosporium*) can be achieved by seed treatment. Over the last 20 years more than 100 different chemicals for seed treatment were tested; the following were recommended for use: Vitavax 200FE, Fenoram, Vitatiuram; (Carboxin group); Benomil, Fundazol, Kolfugo-Super, Triazolon-Sumi 8, Raxil, Dividend, Vinsit, Prens (Benzamidazol-karbomat group). These chemicals are highly effective against common bunt and loose smut, *Septoria* and *Helminthosporium*. They also suppress the development of mold. The toxicity of these fungicides for humans and animals is ten or hundred times lower compared to chemicals containing mercury (Granozan, Mercurgexan). Seed treatment provides yield increase in a range of 0.15-0.20 t/ha.

The development of soil and stubble pathogens (root rots, *Septoria*, *Helminthosporium*) depends on the preceding crop and agronomy in general. Normally the level of infection by root rots does not exceed 10-15% and yield losses – 5-7%. Durum wheat is more susceptible to root rots. The following preceding crops are recommended to control

root rots: sweet clover, oats, maize, winter rye, millet, mixture of cereals and legumes.

The next group of diseases are airborne pathogens such as leaf and stem rust, powdery mildew, *Septoria* and *Helminthosporium* leaf blotches. The latter may be transmitted through the seed or remain on wheat debris. The distribution and severity of rusts largely depend on the presence of infection which comes from the Northern Caucasus, Stavropol region, Western Siberia and other regions of the Russian Federation. It was discovered recently that local sources of rust infection (winter wheat) also play a significant role. Agronomy and crop rotation do not influence rust distribution.

During the 1974-1996 period localized epidemics in Northern Kazakstan occurred eight times, damaging up to 25% of wheat area. Significant infection by stem rust was observed only once. *Septoria-Helminthosporium* leaf blotches were observed eleven years or every second season sometimes damaging up to 42% of the crop. The Institute developed wheat protection measures to control airborne diseases mainly based on application of fungicides such as Alto, Impact, Tilt, and Folicur. A methodology was developed to estimate the need for chemical application depending on the level of disease pressure and a number of other factors. It was observed that epidemics of leaf rust and *Septoria* occur in years with high air humidity in July and August. During 7-10 days these diseases can spread over hundreds of thousands of hectares and in some years up to 3 mln ha.

In the former Soviet Union great attention was paid to research on rusts and *Septoria* as possible tools of biological warfare. The network of research institutions constantly monitored seasonal and long-term changes in rust populations including the virulence pattern. Airplanes were used to trace major rust migration routes, which were confirmed, by trap nurseries all over the country. After the break-up of the USSR, this work stopped. It is however very important to continue monitoring rust and *Septoria* populations using air and space observation as well as to expand the network using new computer methods of data management.

One of the most important methods of disease control is cultivation of resistant varieties. The Institute is evaluating the reaction of wheat germplasm to disease. Unfortunately, of 70 varieties tested none was resistant to major pathogens. Only five varieties (Karabalykskaya 90, Karabalykskaya 91, Akmolinka 2, Akmolinka 3 and Kenzhegali) were relatively resistant to leaf rust but highly susceptible to loose smut. None of the winter wheat varieties tested was resistant to dwarf bunt.

Weed control plays a major role in the increase of wheat production. The losses due to weeds may reach 40%. There are around 300 weed species that can be found in cereals in Kazakstan. The most widely spread and harmful are wild oats (*Avena fatua*), cornbind (*Convolvulus arvensis*), field sawthistle (*Sonchus arvensis*), tickseed (*Corispermum declinatum*), Canada thistle (*Cirsium arvense*), couch-grass (*Agropyron repens*), yellow foxtail (*Setaria glauca*),

barnyard millet (*Echinochloa crus-galli*), common wormwood (*Artemisia absinthium*), redroot amaranth (*Amaranthus retroflexus*), fat hen (*Chenopodium album*), and turgenia (*Turgenia latifolia*). For instance, the presence of 50 plants of wild oats per m² reduces yield by 26%.

In our country the distribution of weeds in the fields is high. This is mainly due to less soil cultivation and the limited supply of herbicides. In addition, the long-term application of herbicides like 2,4D resulted in the development of resistance in some weed species. This is especially obvious in minimum tillage fields where grass weeds are very common.

The country is divided into several regions depending on the dominance of particular weeds: wild oats-suckering weed type; couch grass-sedge type; yellow foxtail-cornbined type and mixed. In the black soils of the steppe zone in Northern Kazakstan, wild oats, cornbined and thistle are the predominant weeds. Annual weeds (tickseed, Russian thistle, green foxtail, barnyard millet) dominate in the dark chestnut soils of the dry-steppe zone. Wild oats,

thistles, field bindweed, wormwood, fat fen, and amaranths are more widespread in mountainous and foothill zones. Irrigated fields are affected by the presence of different groups of weeds, both dicotyledonous and monocotyledonous.

Proper crop rotation, the tillage system, and good quality seed are most important in controlling weeds. However, these traditional methods sometimes are not sufficient and herbicide applications are recommended, especially in minimum tillage fields. Herbicides (2,4D, Dezormon, Dialen, Granstar, Puma-Super combi and others) provide yield increase of 0.33 t/ha. Over the last few years, new, third-generation herbicides were released which require applying minimum doses. For example, Chlorsulfuron is active with the dosage of 7-25 g/ha, Lontrel – 50-200 ml/ha and others. The Institute for the first time prepared two new herbicide compositions: aminofur and dikamfur recommended for cereals. These chemicals were patented and the trademarks were registered.

Integrated pest management (IPM) was recommended for crop protection. However, as practice showed, the IPM system turned out to be far from perfect and in many cases was a combination of different methods without taking into account their interaction. The Institute develop an IPM method that involves the application of agronomic measures, cultivation of resistant varieties, chemical and biological control based on predicted development of pest populations, diseases and weeds. This system reflects the current tendency of crop protection without influence on environment. At the same time, several practical issues of application of useful organisms remain unclear: insects, toxins, fungi, mycoherbicides and others. There is intensive research in this area in foreign countries (USA, Canada, France, Italy and others). During the transition period of agriculture in Kazakstan, IPM did not receive proper attention despite its undoubted economic, ecological and social advantages. Unfortunately, we do not know how to use this approach in crop protection. The observation of recommended crop protection measures would lead to increased grain production.

Spring Wheat Protection in Northern Kazakhstan

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Spring wheat occupies more than 12 mln ha in Northern Kazakhstan. Variable environmental conditions of wheat cultivation determine the variability of pests, diseases, and weeds. Many of them can significantly reduce yields in favorable years. The most common weeds are perennial rootsuckers such as Canada thistle (*Cirsium arvense*), sow thistle (*Sonchus arvensis*), prickly lettuce (*Lactuca tatarica*), field bindweed (*Convolvulus arvensis*), Russian sweet sultan (*Acroptilon repens*); rootstock weeds represented by quackgrass (*Elytrigia repens*), sedge (*Leymus ramosus*) and annual weeds such as wild oats (*Avena fatua*), green bristle grass (*Setaria veridis*), yellow foxtail (*Setaria glauca*), amaranth (*Amaranthus retroflexus*), fat hen (*Chenopodium album*), and black bindweed (*Polygonum convolvulus*). Recently as a result of changed relationships between producers and consumers, and low levels of agronomy and crop protection, practically two-thirds of the spring wheat area is weed infested to a high or medium degree, and more than two-thirds is damaged by diseases and pests.

The most important diseases of spring wheat are loose smut, root rots, septoria leaf blotch, *Helminthosporium* leaf blight, and leaf and stem rust. In epidemic years (1993-94), yield losses due to septoria have reached 30-35%. There is a

similar situation with wheat pests. Almost annually spot and mass distribution of locust, thrips and Hessian fly is observed. Early planting has resulted in appearance of the gray grain cutworm, which was observed very rarely three or four years ago.

Integrated pest management (IPM) meets current crop protection requirements. It regulates the frequency of harmful and useful species in the environment and limits development of pests, weeds and diseases to economically safe levels. The success of IPM largely depends on proper agronomy and the use of good quality seed. First-class seed of released high-yielding varieties treated against smuts and bunts as well as other diseases should be used for planting. Protection of wheat against pests, diseases and weeds depends on the tillage system. Proper and timely soil tillage enhances moisture accumulation, cleans fields of weeds, and reduces the number of thrips, cutworm and other pests. Optimal soil moisture protects the crop from root rot damage and reduces the damage from wheat flies, thrips and other pests. Having enough moisture in the soil, wheat seedlings even when highly damaged by the stripe flea recover very fast, and the number of tillers per plant is not reduced.

Optimal sowing dates are nearly the most important factor for protecting wheat from pests, diseases and weeds.

Wild oat infested fields are planted at the end of the optimal planting date so that the weed can be destroyed by cultivation prior to planting. With delayed planting sensitive stages of development coincide with the accumulation of pathogens that cause rusts, root rot and viruses, which results in a higher level of infection. On the other hand delayed planting reduces damage by the gray grain cutworm. Application of mineral fertilizers, phosphorus particularly, reduces the vegetative period of wheat by 5-6 days thus reducing grain damage by gray grain cutworm larvae and aphids. An early and short harvesting period is very important for wheat protection against pests. Timely wind-row threshing of wheat decreases losses by corn weevil, thrips and sawfly. A 10-day delay in harvesting increases losses caused by grain cutworm to 40-50 kg/ha. Early and short harvesting is also very important due to the fact that many cutworm and thrips larvae are not able to complete their development, which reduces population size.

Crop rotation is a very important agronomic method to combat pests, diseases and weeds. The best preceding crops for wheat are fallow, perennial grasses and legumes. They substantially reduce root rot damage. The development of proper crop rotation stabilizes weed development. Cultivation of resistant wheat varieties is also important for

protecting against diseases and pests. According to data from the Southeastern Agricultural Research Institute, varieties with a short tillering period are resistant to cereal flies. Research at the All-Union Institute of Crop Protection showed that durum wheat varieties with leaves without hairs are highly resistant to Hessian fly. It is also known that wheat varieties with solid stems are resistant to sawfly.

Though agronomic protection measures are important, they cannot completely protect the crop and, therefore, the application of chemicals is important. The application of more than 20 chemicals for seed treatment was studied and the following were recommended for industrial use: Dividend, Vitavax 200, Vinsit, Vitatiuram, Cumy 8, Raxil and others which are highly effective against common bunt and loose smut as well as root rot and septoria. The following fungicides are effective against *Helminthosporium* leaf blotch, septoria, and leaf and stem rusts: Tilt, Tilt-Premium, Impact, Foilicur, Granit, Alto, Bamper and others. Effective chemicals against wheat pests are: Metafos, Desis, Sumy-Alfa, Karate and others.

A system of herbicide application was developed for the fallow-wheat rotation, which allows to completely clean the fields of weeds. Agronomic and chemical protection methods against perennial root weeds (quackgrass and sedge) were developed. Several herbicides were tested against wild oats such as triallat, avadex BV, Granulated Fortress and Flutar (soil application); Illoxan, Assert, Puma-Super, Topic (seedling application). All of them showed high efficiency and killed 80-97.5% of wild oats plants. The best were granulated and liquid forms of triallat for soil application and Topic, Puma-Super for seedling application.

The application of a combination of chemicals is a promising method to combat weeds. In Northern Kazakhstan long-term application of 2,4 D resulted in the increased population of species that are resistant to this herbicide, such as black bindweed and amaranth. Herbicides have to be applied twice to fields with wild oats resistant to 2,4 D. All this encouraged the experiments with the two or three component mixtures of herbicides against dicotyledon weeds and grasses. The best results were demonstrated by the following mixtures: Tresor + Topic, Buktril + Topic, Granstar + Topic, Buktril + Puma-Super, Granstar + Puma-Super. Positive results were also obtained by application of combined Puma-Super Combi.

Field application of chemicals should be viewed realistically. There was a time when any chemical application was considered negative and polluting to the environment. Producers were in doubt. Now the situation is very clear, in the sense that everyone has realized that wheat production without chemical protection is not possible, and reduced pesticide applications over the last few years is explained merely by the difficult economic situation. It also has to be considered that the ultimate objective of pesticide application is not to kill harmful organisms but rather to create conditions for the crop to express its yield potential. The results of chemical application should be evaluated based on its effect on yield and grain quality. For agrocenosis (field biodiversity) the chemical definitely represents a major stress and if applied systematically will result in ecological problems. Therefore, their effect should be considered not on a crop level but on a biocenosis level taking into account all the structural and functional relationships within the specific environment. To implement this approach, ecological monitoring in each crop production region should be conducted to evaluate the possible negative consequences of chemical application. Sound application of pesticides combined with agronomic methods will allow to reduce the population of pests, diseases and weeds in spring wheat to the level where they are no longer harmful.

Genetic Resources and Results of Wheat Breeding in Kazakhstan

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Wheat is among the most important crops in the Republic of Kazakhstan, and it guarantees the security of the nation. The area under wheat (winter, spring) varies from 12 to 14 mln ha, and accounts for more than 40% of all arable land in the Republic.

Kazakhstan produces more than 25 mln t of wheat grain and is one of the largest producers of high-quality grain in the region.

In Kazakhstan wheat breeding started in 1910 at the Krasnovodopadskaya State Breeding Station. In the 1930s several other breeding stations were opened: Karabalykская, Shortandinskaya, Almatynskaya, and Uralskaya. In 1935 they were included in the network established by the Kazak Agricultural Research Institute which became the coordinating center for breeding research and seed production. As a result of long-term experiments (1964-1978), major wheat breeding objectives for different ecological zones were determined. Because of its climate (frequent spring and summer droughts), Northern Kazakhstan requires intermediate maturing varieties with a long tillering period (Siberian type) and superior grain quality.

In Kazakhstan about 70 mln ha have salinity problems. Therefore a main objective of spring wheat breeding is salt tolerance. Other important traits are drought and heat tolerance, resistance to major diseases and pests, and high grain quality. Ideotypes of spring bread and durum wheat varieties were developed for:

- rainfed conditions of Southeastern Kazakhstan
- irrigated conditions of Kazakhstan
- drought-prone zones of Western Kazakhstan

Since 1982 spring wheat breeding is conducted at the Kazak Agricultural Research Institute as part of the Ak-biday and Grain programs. The research concentrates on multilocal study of advanced germplasm in major wheat producing regions of Kazakhstan and Siberia. As a result of targeted breeding over the last 10 years, 25 spring wheat varieties were developed and submitted to the State Variety Testing Commission. These varieties vary in adaptation and maturity but all have superior grain quality classified either as strong and or valuable wheat. Ten of them have been released and two will be released in the near future. A brief

description of some of these varieties is listed below:

1. *Kazakstanskaya rannespelaya* - early maturing, lutescens. Maximum yield was 5.44 t/ha. Superior quality strong wheat: protein content 14.8 – 17.1%; wet gluten content 32.0 – 37.0%; alveograph value 400 - 536 a.u. Cultivated in Kostanay, Kokshetau, North-Kazakhstan regions of RK and Chelyabinsk region of Russia on a total area of 0.8 mln ha.
2. *Kazakstanskaya 10* - intermediate maturing, lutescens. Cultivated under irrigated and rainfed conditions. Maximum yield of this variety: 8.02 t/ha. Grain quality is classified as valuable wheat: protein content 15.0-16.7%, wet gluten content 32.0-37.6%, alveograph value 340-494 a.u., loaf volume 1100-1300 ml. *Kazakstanskaya 10* was released in Bashkortostan (Russia), Kyrgyzstan, Almaty, and Kyzylorda regions on 0.25 mln ha.
3. *Kazakstanskaya 15* - intermediate-late maturity, lutescens. It has remarkable drought tolerance, lodging tolerance and adult plant resistance to rust. Quality is classified as strong wheat: protein content 15.0 – 16.3%, wet gluten content 31.0 – 34.0%. Maximum yield – 5 t/ha. Cultivated in Kokshetau, Akmola, and Pavlodar regions on 0.2 mln ha.

4. *Kazakstanskaya 17* - early maturing, *lutescens*. It is characterized by lodging tolerance. Yield potential is 5.8 t/ha. Superior quality (strong) wheat released in Semipalatinsk and Western Kazakstan regions. Area is 10,000 ha.
5. *Kazakstanskaya 19* - intermediate-early variety resistant to loose smut. Maximum yield 4.3 t/ha. Strong wheat: protein content 15.8-16.0 %, wet gluten content 35.5-36.5%. Released in Kostanay and Pavlodar regions and occupies 15,000 ha.
6. *Lutescens 32* - early maturing variety. Yield potential: 5.63 t/ha. Strong wheat. In Northern Kazakstan produces the best results with a late planting date. Since 1996 has been released in Kostanay and Pavlodar regions.
7. *Kazakstanskaya 25* – intermediate maturing variety. Grain quality is classified as strong wheat: protein content - 14.6%, wet gluten content – 30.5%, alveograph value 459 a.u., loaf volume 1123 ml. Maximum yield 4.50 t/ha. Released since 1997 in the Kostanay region and in pre-release stage in the Aktobe region.

Basic research on spring wheat at the Kazak Agricultural Research Institute is directed mainly towards improving breeding methodology and concentrates on the following subjects:

- Evaluation of crosses based on F1;
 - Competitiveness of different genotypes at the population level;
 - The dynamics of yield in F1 - F10 generations without selection;
 - Development of monosomic lines of variety *Kazakstanskaya 126* variety to study the role of individual chromosomes in the development of agronomic traits;
 - Development of isogenic lines for leaf rust resistance and grain color for the variety *Kazakstanskaya 4* (Grekum).
- Thus, more than 50 years of spring bread wheat breeding at the Kazak Research Institute of Agriculture resulted in the development of 30 varieties with a wide maturity range and input requirements. The yield increased from 0.45 t/ha in 1940 to 4-5 t/ha in the 1990s. The reason for success: correct methodology, availability of genetic resources, trained personnel.
- The increase of grain production and its stability in the country to certain extent is determined by winter cereals, especially winter wheat. This crop is cultivated in Kazakstan on 1.3–1.5 mln. ha, mainly in the South and Southeastern regions of Kazakstan. The environmental conditions of winter wheat cultivation are very diverse (from semi-desert to highland with precipitation from 150-200 to 600 mm) requiring varieties with broad adaptation. The cooperative winter wheat breeding program "OPAKS" (winter wheat agroecotypes breeding) was established in 1975 to breed for different regions of the country. At present the activities within the program resulted in the development of more than 40 varieties of winter wheat belonging to various agroecotypes: irrigated, highland, and dry-steppe types. Eleven varieties have been released.

Following is a brief description of the winter wheat varieties bred by the Kazak Agricultural Research Institute:

Bogarnaya 56. Released since 1982 in Zhambyl, Taldykorgan, and Kyzylorda regions. Intermediate-early variety. Yield is higher than that of the check variety by 0.10-0.30 t/ha. Good cold tolerance. Good bread baking quality, included in the list of valuable wheat varieties.

Progress. Released in 1984 in Almaty and Kyzylorda regions of Kazakstan and Odessa region of Ukraine. High yielding variety – up to 9.3 t/ha in irrigated conditions. Resistant to lodging.

Almatynskaya Polukarlikovaya. Released in 1985 in Southern Kazakstan. Intermediate-early variety. Good drought tolerance. Excellent bread making quality, included in the list of valuable wheats.

Karlygash. Released in 1985 in Zhambul region. Intermediate maturing variety. Resistant to lodging. Medium cold tolerance.

Opaks 1. Released in 1986 in Almaty region. Intermediate-early variety. Resistant to lodging. Protein content is on the level of check variety; gluten content is higher.

Zernokormovaya 50. Released since 1993 in Taldykorgan region. The variety is characterized by high lysine content in grain and is used for fodder.

Yuzhnaya 12. Released since 1992 in Zhambyl and Southern Kazakstan. High-yielding variety. Included in the list of valuable quality wheats.

Zhetysu. Released since 1993 in Almaty, Taldykorgan, Zhambyl and Southern Kazakstan regions. High yielding variety –3.0 to 6.3 t/ha. Valuable wheat.

Komsomolskaya 1. Released since 1993 in Almaty region. High yielding variety. Good cold resistance and good bread baking quality.

Steklovidnaya 24. Released since 1995 in rainfed areas of Taldykorgan, Zhambyl, and Southern Kazakstan regions and in Osh region of Kyrgyzstan. Drought resistant. Vitreousness is 95%. Bread making quality is excellent, included in the list of superior quality strong wheat.

Eritropermum 350. Released since 1995 in Almaty region. High-yielding variety. Cold-and drought tolerant with good bread making quality.

The most effective breeding methods applied in Kazak Agricultural Research Institute:

- Selection of constant lines from segregating populations.
- Different crossing schemes to obtain desirable gene combinations and transgressions (diallel, topcross, back-cross, directed polycross with the parental genotypes differing in morphological traits, double-cross, test composite cross, step by step crosses and their modification);
- Experimental mutagenesis (physical and chemical) and its combination with hybridization;
- Intravarietal somaclonal variation
- Biotechnological methods;
- Cell breeding;
- Wide hybridization (interspecific and intergeneric) combined with embryo culture.

Genetic resources of plants represent the most valuable and strategically important capital of any country, since they are directly linked to the food supply at present and in the future. The reason for our emphasis on genetic resources conservation and germplasm exchange is genetic erosion. According to some evaluations, commercial varieties capture at present no more than 5-8 % of existing genetic diversity. The threat of complete disappearance of traditional local varieties, and fast shift to newly developed varieties also make it necessary to utilize the world genetic resources and provide for long-term storage of germplasm. Establishing a wheat gene bank is of great importance for Kazakstan, where intensive wheat improvement has resulted in genetic erosion and there is a need to maintain genetic diversity.

The genetic resources concentrated in the Kazak Research Institute of Agriculture (in seven breeding programs) account for more than 13,000 accessions, which make up 50% of the national crop collection (23,053 accessions). At present international cooperation on plant genetic resources is maintained with seven institutions:

- International Center of Vegetative Resources, Osaka, Japan;
- CIMMYT, ICARDA;
- International Center of Winter Wheat Breeding, Cambridge, England;
- American Corporation of Corn Breeding and Seed Production “ Dekalb ”;
- Institute of Genetic Resources, Urumchi, China;

- Institute of Wheat “ Dobrudzha ”, Tolbuhin, Bulgaria;
- Institute of Corn “ Zemun pole ”, Belgrade, Yugoslavia.

At present the genetic resources maintained in Kazak Agricultural Research Institute involve all categories of germplasm including genetic collections of *Rht*, *Sr*, *Lr*, *Bt*, *Vrn*, and *Ppd* genes. These genetic resources are systematically evaluated to discover genetic potential of the gene pool. Protein markers (prolamin and glutenin) are used for identification. A substantial number of entries was tested for the presence of different alleles of storage proteins: 3 allelic variants of glutenin-coding locus Glu 1A were detected, 5 - locus Glu 1B and 6 alleles of locus Glu 1D. All varieties of Kazak Agricultural Research Institute have high molecular weight subunits of glutenin 2* controlled by locus Glu 1A. The most frequent subunits controlled by locus Glu 1B are 7+8 and 7+9 (84 %) and by locus Glu 1D - 5+10 (50 %), 3+10 (22 %), 5+12 (16 %).

In 1995 trials 100 samples from Iran (ICARDA) were evaluated and the following selections made:

- high number of grains per spike - 21 entries;
- 1000-kernel weight - 19 entries;
- grain weight per spike - 32 entries.

In 1996 trials two nurseries from Turkey-CIMMYT-ICARDA (5 FAWWON - 210 entries and EYT - 25 entries) were evaluated under irrigated conditions and the following selections were made:

- grains per spike - 64 entries;
- 1000-kernel weight - 120 entries;
- grain weight per spike - 50 entries.

Cell and Gene Biotechnology on Cereals in Kazakhstan: Some Results and Perspectives

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The development of the ideas and tools of plant physiology and cell biology has resulted in new methods of cell and genetic engineering as the basis of modern biotechnology. Most biotechnological methods are based on cell culture. Their value is determined by their potential for solving applied and basic biological problems as well as for developing new methods. Nevertheless, these possibilities remain largely unrealized as far as practical plant breeding is concerned. This limitation has to do with several problems relating to plant regeneration from cell and protoplast culture, cell breeding and genetic transformation, our limited knowledge of cell and molecular processes and mechanism of morphogenesis of *in vitro* culture. In our work we are focusing on solving these problems for wheat and maize. These two crops are especially important not only because of their vital role in human and animal diets but also because of the challenges they present to biotechnologists. These two crops are very difficult to cultivate *in vitro* using cell culture and genetic engineering methods. This presentation reviews 10 years of research in the genetic engineering department at the M.A. Aytikhodjin Institute of Molecular Biology and Biochemistry devoted to the study of physiological and biochemical properties of cell culture of cereals

and the development of new biotechnological methods for breeding.

According to the objective of the research, all the work may be divided into three topics. Firstly, there was research to study the regeneration capacity of cell culture of wheat and maize, determination of optimum conditions for regeneration and the development of efficient cell models and experimental systems. Secondly, the models and systems developed were used to study photosynthesis, morphogenesis, resistance to stresses, and cell activity in outer space. Thirdly, the work concentrated on the biotechnological aspects of practical application of wheat and maize cell culture.

Factors affecting the development of callus and plant regeneration

A major result of this work was the genetic analysis of callus formation process and plant regeneration which concluded the following:

- a) Callus formation and plant regeneration are not related processes and are apparently controlled by different genetic systems.
- b) The female parent plays a very important role in the expression of the regeneration activity of the hybrid, indicating the importance of cytoplasm genes for *in vitro* morphogenesis.

- c) The regeneration capacity of wheat is mainly inherited as intermediate or overdominance.
- d) Complementary epistasis of recessive genes determines regeneration capacity.

The results show genetic determination of regeneration capacity and its dependence on cytoplasmic and maternal effects. Summarizing the results of the genetic analysis of the morphogenesis processes *in vitro* it should be emphasized that the genotype is expressed in a specific environment and while modifying the conditions the potential of the genotype could be manifested.

The regulatory role of environment in multiplication of the cultured cells is the basis of the so-called "gradient approach" which is being developed to solve the problem of differentiation *in vitro*. Two facts were instrumental in the development of this approach. Firstly, regenerating plants from cell culture originated from wheat leaves, which traditionally are considered to have low regeneration capacity. This was achieved by stepwise changes in the environment, i.e., increasing or decreasing the concentration of hormones and light intensity. Secondly, long-term cell cultivation results in the dramatic decrease or complete loss of regeneration capacity. It turned out that if the concentration of hormones is

changed with each subculture, this extends the morphogenetic activity of cells and even increases cell biomass.

Thus, utilizing certain factors it is possible to fine-tune morphogenetic processes in cell and tissue cultures. It is primarily based on the development of certain gradient of factors between the media and cultured tissue. With this gradient approach, any factors resulting in the increased cell heterogeneity will be positive for cell differentiation and the formation of morphogenesis initiation spots. The factors which lead to homogenic distribution of cells in media demonstrate the opposite effect. As was shown, in outer space the frequency of the formation of morphogenic callus and plant regeneration decreases. The gradient approach illustrates the importance of environment for cell differentiation.

Development of effective cell models and systems

Most research conducted so far on cereal cell culture has concentrated on using calli and solid media. However, at present there is a need for more efficient cell models and experimental systems.

Suspension culture. This is a promising approach that has worked for many plant species. However, its application to cereals remains very difficult. After several years of research, we obtained a suspension culture with a high frequency of embryogenic cells capable of regeneration. This approach was based on two methodological principles. Firstly, selection of the callus culture prior to its introduction into liquid media. Only cells capable

of metabolic change, cell division and of maintaining morphogenic potential under conditions of deep cultivation could be a source for real suspension culture. Secondly, the variation of the conditions of the suspension culture favorable for the division of the certain cell type. Frequent subcultivation of the suspension in such media enriches the suspension with embryogenic, actively dividing cells. An embryogenic suspension culture is bright yellow. It is highly dispersed and morphologically uniform, consisting of round and oval cells with dense cytoplasm, clearly pronounced nucleus, and cytoplasmic threads.

Protoplast culture. Only 10 years ago it was considered very difficult if at all possible to regenerate wheat plants from protoplasts, conduct genetic transformation using cereal protoplasts and obtain transgenic plants. Today this is a reality; the critical factor for success was developing embryogenic, actively proliferating cell suspensions. Using cells from the suspension culture, we managed to obtain dividing protoplasts and regenerate the plants.

Our approach to developing embryogenic cell suspensions and regenerating plants from isolated protoplasts is not based on the identification of unique "regenerating" genotypes but on a selection of totipotent cells. This is very important because it allows to obtain necessary culture for any wheat and other genotype. Using this methodology we managed to develop the maize suspension cell culture, isolate the protoplasts, and regenerate the plants.

The main result of the first part of the work is the development of an approach to identifying totipotent cultured cells and create effective models and systems. Using these models we tried to study some important processes of cell and plant activity.

Physiology and biochemistry of cultured cells

Photosynthesis. It is shown that while using the cultured cells very wide variability of this process can be induced. Our experiments determined carboxylase and oxygenase activity of Rubisco in several wheat genotypes created with the help of cell biotechnology. The activity of this enzyme determines the relative speed of photosynthesis and transpiration. It is interesting that one genotype was identified to have a modified ratio of the two sides of Rubisco activities - it had higher carboxylase activity. Up to now it has not been possible to change this ratio using other methods. This is important since it allows the plant to reduce transpiration, which sometimes consumes 50% of photosynthetic products. This result is very important for genetic reconstruction of photosynthesis using cell technologies.

Morphogenesis. Data obtained from one- and two-dimensional electrophoresis of proteins indicate that the transition of a wheat embryo into callus is accompanied by remarkable changes in the composition of the cytoplasmic proteins. There is an increase of low molecular polipeptides. During callus differentiation, synthesis of polipeptides with a molecular weight of 22 and 27 kd increases. In maize

there is a dramatic increase of polipeptides with a molecular weight of 70, 50, 35, 27 kd and one novel protein of 43 kd appears. The polipeptide of 27 kd is characteristic of morphogenesis *in vitro* in maize.

An important stage of post translation protein modification in eucariots is phosphorilation, which regulates their activity. In embryos the polipeptides with molecular weights of 70, 60 and 50 kd are phosphorilized and only when the callus reaches the morphogenic stage do phosphorilized polipeptides of 70 and 50 kd appear again. So *in vitro* morphogenesis is connected to significant changes in protein composition. Of course not every protein in the induced tissue is morphogenic, but synthesis of some proteins and peptides may be connected directly to *in vitro* morphogenesis. A peptide with 2 kd molecular weight was extracted from embryogenic maize callus. Its synthesis sharply increases when the callus reaches the morphogenic state. When used as an exogenic additive, this peptide stimulates plant regeneration.

Outer space. Cell culture is uniquely suited to be the subject of experiments in outer space because it is a model of all development stages of biological systems: cultured somatic and sexual cells, dividing cell aggregates, differentiating cells and embryogenesis, formation of plant organs and the whole plant. Using cultured cells of wheat, maize and potato, we studied the effect of outer space on major biological processes: growth and development, division and differentiation of cells. The

division of maize cells in outer space went through two stages. The first stage (10-12 days) is characterized by the adaptation of the culture and was stressful. It is accompanied by suppression of cell activity, and division and death of a substantial number of cells. Correspondingly, the frequency of stress tolerant cells increases. These cells at the second stage start actively dividing because weightlessness results in uniform cell distribution in the population and reduces the gradients of nutrient elements. Taking into account the mutagenity of space radiation, these processes can be utilized for effective selection of stress resistant cells. Independently of the length of exposure to space, development processes in the cell culture slowed down. One of the reasons could be independence of cells distribution in the population and weakening of the interaction between cells.

Data analysis shows that gravity is necessary for cell culture. It results in heterogeneity of growing cell structures and induces cell differentiation. In our opinion the multiplication and development of the earth organisms in space will be difficult if at all possible due to the absence of gravity and the weakening of the contact between cells. This should be taken into account in developing programs for future space exploration.

Biotechnological aspects of utilizing cultured cells of wheat and maize

Recently cell culture received a powerful boost due to the possibility of conducting cell and genetic engineering utilizing the methods of modern biotechnology.

Somaclonal variation. This is one of the simplest applications of biotechnology based on genetic changes of cultured cells and regenerated plants. These changes may involve different aspects of cell and plant activity including agronomically important traits. In Kazakstan this method has found wide application, and a number of lines and varieties have been developed using somaclonal variation.

Cell selection. Further improvement of this technology is cell selection based on screening genetically altered cells using the selective factor followed by plant regeneration. Screening can be done in the presence of different stress factors such as toxins of pathogenic fungi. This approach is used to enhance resistance to septoria. Utilizing cell selection, it is possible to identify a wheat cell line resistant to septoria toxins within 8-10 months. Despite the superficial simplicity, cell selection poses several challenges. First of all the selection process must be quick because the *in vitro* culture loses its ability to regenerate with time. One way to shorten the cell selection period and widen genetic changes may be to do it in outer space.

As was mentioned above, plant cells acquire stress tolerance after being exposed to the weightlessness, in particular, resistance to septoria toxins. A series of experiments were conducted in which a cell culture was exposed to septoria toxins during one month in space. The data showed that a toxin concentration that suppresses the cell culture in normal conditions four times practically did

not affect it in space. Under normal conditions it takes one month for the cell culture to reach a similar level of resistance. Enhancement of cell selection efficiency in space is not unexpected taking into account the combination of several factors: somaclonal variation, mutagenity due to space radiation, weightlessness which in general affects positively single cells and small aggregates *in vitro* cultures. This justifies the identification of a new area of research – space biotechnology. The application of cell selection in space coupled with traditional breeding methods resulted in a new potato variety released by the Kazak Institute of Potato and Vegetables. It is stress tolerant and was named Tokhtar to commemorate the first Kazakh cosmonaut Tokhtar Aubakirov.

Genetic transformation. Plasmids pMGP1 and pNA2G containing marker genes for beta-gluconurase, neomycinphosphattransferase and phosphintrinsicatsetiltransferase were used for transformation. The beta-gluconurase (GUS) gene codes the enzyme responsible for digestion of

glucuronid. To determine the activity and localization of the enzyme in cell and tissue, special substrates are added which form stained products digested by the enzyme. The gene for neomycinphosphattransferase conditions resistance to the antibiotic kanamycin, and the gene for phosphintrinsicatsetiltransferase, resistance to the herbicide phosphinotricin.

Maize transformation was achieved using these genes while applying polyethylenglicol to the isolated protoplasts. Identification and selection of transformed cells was based on the resistance to kanamitsin and phosphinotricin and the staining of cells in the presence of GUS activity. The presence of foreign genes in the genome of transgenic plants was detected using PCR and Southern blotting. The transformed genes were inherited and expressed in the following generations. The beta-gluconurase gene was more active in aging leaves than in young leaves. This was expressed in the leaf epidermis and mesophill, the stem conducting system, and the roots.

Transgenic plants had normal growth and development in the media with phosphinotricin, while the control plant died. One of the latest methods developed was wheat genetic transformation using mature embryos and microthreads of silicon carbamide. The method is based on simple mixture of mature wheat embryos with microthreads of silicon carbide in a solution of alien DNA. Penetration of the DNA in the cells is possible due to the holes in the cell membrane made by the very fine microthreads of silicon carbide. The advantage of this method compared to cell culture and isolated protoplasts is obvious.

The conclusion of our work is that useful biotechnology is not created based on unique "regenerating" genotypes or universal culture conditions but rather on general principles that take into account the dialectic unity of the genotype and environment, as we tried to show in this presentation.

Applying New Genetic Methods in Breeding Self-Pollinated Crops

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The main objectives of breeding are development of the variety model for each region, the study of parents, selection of parents for hybridization, and selection and evaluation of genotypes suitable for agricultural production. Together with the breeders we have studied the possibility of utilizing genetic-statistical methods to improve the efficiency of breeding the major self-pollinated crops: wheat and rice (1, 2, 3, 4, 5, 6, 7, 8, 9).

The concept of a model and variety ideotype is important in modern breeding and genetics (10). The theoretical justification of this concept is the high degree of interrelationship between yield components and other phenotypic traits such as the expression of the plant as a whole and its development. The genetic improvement of one component is often compensated by the others (11, 12). The breeder's objective is to find the optimum expression of the traits of interest, not necessarily its maximum.

Historically our understanding of the ideotype originated in the plant type concept (13) that allowed the rough determination of the principal mechanisms responsible for different reaction of genotypes to mineral nutrition, high crop density, genotype mixtures, and other factors (14). The practical application of the plant type

concept in the course of the Green Revolution played a major role in the creation of a number of the new wheat and rice varieties (14, 15).

The importance of this concept is not determined only by the breeding process, which requires well-defined targets and direction. It is well known that the model of a variety to large extent determines the breeding methodology. Practical breeding experience indicates that good productivity can be only achieved using ideotypes with good physiological, ecological, and evolutionary determination regarding a number of traits (10, 16). That is why the creation of varietal models requires a multisystems approach that would allow using many factors in a format that can be easily demonstrated.

At present, factor analysis best meets these requirements. Researchers are learning how to interpret "plant types" identified using the main components method (17). Such interpretation differs from the traditional approach targeted towards identifying the major internal reasons for the interrelated variability of the traits. Factor analysis may not be appropriate for solving problems with high precision. It is based on correlation matrices and correlation coefficients are

known to have limited capacity due to normal distribution and the linear relationship. Factor analysis itself is based on linear models, which results in oversimplification of the situation. However, its suitability is beyond doubt for making rough estimates of the structure of the relationship among traits and classification of objects.

A strict quantitative definition of an ideotype's traits is not necessary. Major characteristics of a varietal model may be defined using rough and even semi-qualitative estimates. This is explained both by the complexity of the objects studied and by the low precision of practical breeding experiments whose data has to be used to develop the models for each region.

The methods of components and factor analysis were used: 1) to define the genetic basis of agronomic traits that determine yield and quality of rice and wheat; 2) to study genotype x environment interaction; 3) to develop a model for crop density in rice, and 4) to develop a model of an early and intermediate maturing rice variety for the Northern regions of rice cultivation. These models were used to develop rice varieties adapted to the environment. The work has started to develop models of spring wheat varieties for Southeastern Kazakstan.

The other important genetics and breeding objective is development and genetic study of parental germplasm in order to identify donors of economically useful traits. This was described in detail for wheat by Merezhko (18). Biotechnological and bioengineering methods are being applied more and more frequently to develop parental germplasm. At the same time, molecular markers are more widely used in genetic studies aimed at mapping the genes responsible not only for alternative quality traits but also for quantitative traits (19, 20, 21). Research in this direction is being conducted at the Institute of Physiology, Genetics, and Bioengineering.

At present, the success of any breeding program to large extent depends on the choice of parents for crosses. There are several approaches for choosing parents that Merezhko classified into the following groups: 1) an approach based on geographical diversity; 2) a complementary approach; 3) an approach based on combining ability, and 4) a systems approach. Crosses between ecologically and geographically diverse parents are promising, but appropriate criteria are needed for evaluating their genetic diversity. We conducted a two-stage study to compare different methods for estimating genetic diversity in wheat and barley. In the first stage crosses were made between parents with maximum, average, and minimum diversity without considering adaptation. In the second stage crosses involved entries with different genetic distance but well adapted to Kazakhstan conditions. The data obtained demonstrates that

genetic diversity can be estimated with the help of Makhalanobis distance, Euclid distance, and main components, as well as factor analysis. In selecting parents for crosses, adaptation to local conditions is important, as are maximum genetic distances. Two component analysis allows selecting parents based on the expression of traits in segregating populations and on the genetic distance between parents.

The central part of any breeding methodology is selection, which until now has been based primarily on breeders' experience and on the scale of work at each stage of the breeding process. We compared conventional and non-conventional selection methods (1, 3). In the first stage we compared the classic pedigree method with single seed descent. The latter implies random selection in F2-F4 and homozygote family selection in F6-F8. Each F2 plant selected by this method will be advanced to homozygosity level by planting one seed from each plant per generation. The population involved will be subjected to minimal effects of natural selection resulting in stabilization of gene frequency. The frequency of good lines obtained by this method and the conventional pedigree method is the same but the land needed is less and the breeding period is shortened by 2-3 years.

An experiment was conducted to compare three selection methods on 54 segregating populations of wheat: SSD from F2 till F5, SSD in F2, and then bulk until F5, conventional bulk method (Table 1). The data demonstrate the obvious advantage

of the SSD method. In each generation of populations advanced through the SSD method, the proportion of lines advanced was 5.3, 16.1, and 37.1% compared to 30.6, 4.3, and 8.6% using the conventional method.

The precise estimation of the advanced lines in yield trials depends on soil variability in the experiments. The simplest and most efficient way to correct this deviation is to use the moving means method. Experiments conducted on wheat and rice demonstrated that the moving means method can be successfully utilized especially in unrepeated experiments with a large number of entries. An environmental index can also help in reducing genotype x environment interaction.

As a result of research conducted at the Institute, the following non-traditional methodology can be used for breeding self-pollinated crops: 1) development of varietal models taking into account genotype x environment interaction; 2) selection of parents based on genetic distance estimated using component analysis; 3) use of SSD for selection and generation advance, and 4) yield trials using the moving means and the environmental index methods.

Table 1. Relative efficiency of different selection methods.

Generation	Year	Number/percentage of lines advanced		
		SSD	SSD-Bulk	Bulk
F2	1990	7939	7939	7939
F3	1991	417/5.3	5092/64.1	2430/30.6
F4	1992	67/16.1	574/11.3	105/4.3
F5	1993	25/37.3	32/5.6	9/8.6

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Mechanisms of Grain Supply and Distribution in Kazakhstan

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One of the most important indices of the standard of living in any country is the supply of food products necessary for normal existence and development. Grain products have special significance. Wheat plays an important role in supplying the world population with food. There are very convenient methods for storing and transporting wheat grain. Because of the high nutritional quality of wheat products, the crop has become the most widespread cereal, and bread is the main dietary component in many countries around the world.

Every year 1.9 billion tons of grain are produced (1992), of which 560 mln t is wheat. The per capita consumption of wheat is 353 kg a year. Increasing wheat production through land expansion is no longer possible, and intensive methods of achieving productivity gains are becoming more and more expensive. Though population growth rate is decreasing, concerns about food security are increasing because there is practically no grain production growth in the world.

Global grain production is not equally distributed by regions. Asia is the principal producer. According to FAO data, grain yield in 1994 was 900 mln t, which constitutes 46.1% of the world harvest. The second largest wheat producer is North America, where 400 mln t were harvested

(20.5%). In CIS countries grain production is 149 mln t (7.6% of world production). In the former Soviet Union in the 1980s the average annual grain production was 185 mln t (about 12% of world production).

In Kazakhstan average grain production in 1990-1996 was 18.0-18.5 mln t, which is 1.5% of the grain produced in the world. Per capita consumption in Kazakhstan is 1090 kg/yr, three times more than the world average. Kazakhstan's share of world wheat production is about 3%. During the years of the reforms, Kazakhstan's grain market went through significant changes in the distribution of production holdings. In 1991 practically all the grain (99.5%) was produced by the state (state farms and collective farms); by 1996 the situation had changed, and only seed production farms and experiment stations were still state property.

Cereal crops must be cultivated on large-scale farms. In 1996, 15.7 mln ha of cereals (91%) were sown by large enterprises, such as joint stock companies and production cooperatives. They produced 10.2 mln t of grain, which constitutes 91.3% of the total grain harvest of 11.2 mln t. The share of small-scale farms in grain production is not big. They produce only 8.5% of the total grain. All farms, small and big, private and state-owned, have

suffered lately from an unfavorable economic situation: price and rate disparity, high inflation rate, non-payment, in-kind payment (barter), breaks in existing supply and marketing systems, etc. This was followed by:

- reductions in input and production levels;
- insufficient use of biological yield potential of cereal crops;
- reduction in production of high quality durum and hard wheat varieties;
- increase in forage use of food cereals.

Due to malfunctioning of the privatization mechanisms, the debt load of the enterprises became so high that when farms were privatized, their cost would not cover the debts. At the same time significant price disparity occurred: prices for industrial goods grew 6.5 times faster (and transportation prices grew 2.2 times faster) than those for farm products. As a result the share of loans in agricultural production costs reached 70%. More than half of the loans are overdue. There is practically no possibility of obtaining long-term loans. As a result, agricultural producers have not purchased new farm equipment for 5-6 years. The index of machinery use is 1.6, which indicates that farm equipment is used 60% longer than

its designated period. Compared to 1990 the number of tractors, combine harvesters, and reaping machines decreased by 22.6%, 30.4%, and 31.7%, respectively. That is why despite reductions in the cultivated area, the supply of equipment is still not sufficient.

The problems of providing financial and technical support to wheat farmers are the same as the problems of all other farmers in Kazakstan. Due to errors of the agrarian reform, technical support for agriculture has decreased sharply. Because of lack of funds, farm enterprises cannot replace obsolete facilities or buy necessary inputs (fertilizers, seeds, lubricants, etc). The main reason for this is the poverty of rural producers and the inability of agricultural production to attract outside investment due to its low efficiency.

At present the Republic has a considerable amount of machinery but not enough to fulfill all farm operations over the long-term. As of January 1, 1997, there were 142,300 tractors and 53,900 combine harvesters in Kazakstan, but this equipment has not been renewed in recent years. The purchase of tractors has decreased from 7000 to 1000 per year, and the purchase of combine harvesters has also decreased. As a result 87.4% of tractors have been in use for more than 7 years and 41.9% for over 10 years. In 1996 more than two thirds of combine harvesters had been in operation for more than 8 years.

In 1996, 8.1% of tractors were put out of operation due to age, compared to 5.5% in 1991. For combine harvesters the percentage was 8.5. The reduction in numbers of tractors, combines, and other machines resulted in the overall reduction of the supply of farm equipment. Thus, compared to 1991 the supply of farm machinery decreased by 39% for tractors and 36.3% for combines. Machines are now used over a more extensive area; in 1997 one tractor is used on 180 ha compared to 148 ha in 1991, and a combine harvester is used on 318 ha instead of 269 ha.

The diminishing supply of equipment has brought about a reduction in cultivated area, decreased yields, and shifts towards low input agriculture, which is unfavorable for the national economy. The situation is made worse because machine maintenance has deteriorated due to the lack of funds among rural producers. Maintenance is generally done on the farm. This means that its quality is poor especially when it concerns elaborate repairs.

A state joint stock company Kendala, a well-known enterprise, used to supply producers with equipment. Kendala comprised several regional companies. As a monopoly, it used to have such drawbacks as bureaucratic management, lack of flexibility, neglect of consumers' interests, and high prices. In 1996 Kendala was privatized. Having analyzed the market, Kendala made a decision to lease 400 John Deere combine harvesters. At the same time they deal with small processing

workshops, delivery of brand name equipment, its marketing, warranty service and repairs during all the term of exploitation.

Since 1996 there has been no uniform structure to supply businesses with farm equipment. A structure that will sell equipment to the farm enterprises under market conditions is being formed at present. Deterioration in machinery, seed, and fertilizer supplies has become a production constraint. The reform of previous agrochemical services and reductions in domestic fertilizer production have led to declines in soil fertility. Only 14,600 tons of mineral fertilizers (active ingredient) and 1.1 mln t of organic fertilizers were applied in 1996, which constitute 2.2% and 4.8% of 1991 levels, respectively. Seeds are practically sown untreated (4-5 times less than in 1991). Basically 99% of the wheat area is cultivated using low-input technology and, therefore, the yield potential of the cultivars is not realized. Thus, in 1996, which was a medium dry year, only 0.65 t/ha were harvested, which is 27% less than the average yield for years of this type (Ministry of Environment data show that the average for 1954-95 was 0.89 t/ha). Thus even in favorable years it will be impossible to reach the yield level of previous years.

The reduction in Kazakstan's wheat area greatly affected grain production. This process was chaotic despite recommendations of scientists. Cereals still occupy about 2 mln ha of low productive lands, especially in the western and central regions. At the same time the reduction in area occurred in regions where conditions allow obtaining

high yields (Akmola, Kostanay, and North-Kazakstan regions). This not only resulted in decreased grain production, but also affected its sustainability (yield variation increased 1.5 times).

The structure of cereal area has also changed. The wheat (first of all spring wheat) share increased from 60.2% in 1990 to 71.4% in 1996, which also influenced sustainability of grain production in Kazakstan. This crop spread widely due to its higher prices on domestic and international markets. For instance, domestic prices for barley and oats constitute only 66-69% and 56-59%, respectively, of the price of 3 class wheat. It is only natural that most producers not having the state support choose to grow a more profitable crop. Food grain is even fed to the animals.

Spring wheat production is mainly concentrated in the Northern region of Kazakstan (87.8% in 1996); 6.8% is found in the Central region, 2.9% in the Eastern, and 1.6% in the Southern region. The spring wheat share of total wheat production is relatively low only in Southern Kazakstan. In Northern and Central Kazakstan it constitutes 100%, in Western and Eastern Kazakstan it is more than 90%. On average the highest wheat yield (0.8 t/ha) was obtained in the Northern region of Kazakstan followed by Southern Kazakstan (0.74 t/ha), Eastern Kazakstan (0.67 t/ha), and Western Kazakstan (0.53 t/ha).

Kazakstan has significant resources for grain export. It produced 10.5 mln t of wheat in 1991-1995 and 7.7 mln t in 1996, while the domestic demand for food grains was about 5 mln t. Yet despite the obvious profitability of grain exports, it would be inappropriate for producers to direct their policy to exports only as it may result in negative structural and socio-economic consequences (underemployment, setback in the development of the livestock production and processing industry, interrupted economic linkages within the Republic). Foreign markets should be the logical continuation of a well-balanced domestic market. First of all the grain trade should be organized in the Republic. At present, the regions of Northern Kazakstan have the opportunity to export 5 mln t of grain and more. At the same time shortages in food grain production in Southern, Western and Eastern Kazakstan are about 1 mln t, 0.3 mln t, and 0.2 mln t, respectively. Central Kazakstan can completely satisfy these grain demands.

The data about average prices for wheat flour and bread in different parts of Kazakstan show that the domestic grain market is not adequately developed and that markets in neighboring countries influence it to a large extent. Table 1 shows that the prices of flour and bread are determined more by prices

in towns on the border with CIS countries than by the demand on the domestic market.

The second option for domestic market development is expanding milling and macaroni industries and combined fodder production. The third option is to emphasize the development of animal production.

A well-developed domestic market would allow producers to choose the buyers. It would also address the unemployment problems in the overall strengthening of the national economy. The grain market of Kazakstan is an independent economic system that was regulated too strictly in the past and which the state does not know well. The State Food Corporation cannot keep up with its role, and the volume of grain that it buys is not big enough (a maximum of 889,000 tons or 14% of marketable grain) to regulate the country's grain market. The system of grain marketing is unstable and has many channels.

In the USA, for example, up to 60% of the grain is sold by farmers through regulated channels, through contracts with fixed terms of delivery and at previously negotiated prices. The other channel is farmers' cooperatives where market volatility is also impossible.

Table 1. Average prices of superior quality flour and bread.

Regions	Prices as of 31.03.97 (\$/kg)			
	superior quality flour		superior quality bread	
	in capitals of the regions	in towns neighboring CIS	in capitals of the regions	in towns neighboring CIS
Northern Kazakstan	0.46-0.48	0.53-0.56	0.54-0.71	0.87-0.89
Western Kazakstan	0.46-0.58	0.49-0.58	0.53-0.65	0.90-1.03
Southern Kazakstan	0.44-0.48	0.39-0.91	0.41-0.42	0.34-0.60
Eastern Kazakstan	0.51	0.51	0.59	1.01

At present many enterprises participate in Kazakhstan's grain market. They are:

- the state, which buys commodities using letters of credit and forward contracts;
- commercial companies which use forward and futures contracts, and after harvest buy based on direct deals;
- grain processing enterprises (stock holding associations) that receive grain in exchange for commodities which will later be resold at higher prices;
- private grain processing enterprises that keep grain in longer storage to take advantage of seasonal price fluctuations.

Besides, there are many non-specialized middlemen, most of whom are multi-commodity and may leave the grain market at any time. They are not motivated to maintain long-term relationships with producers and impose tough price pressure on them. Depending on market demand, producers can choose the most profitable channels for grain marketing.

In 1996 almost half of the grain was bartered. This amount is rising very fast, now accounting for almost 45 times more deals than in 1991. Non-equivalent barter exchange is exercised for lubricants and fuel. Their market price is practically the same, but a peasant exchanges 3-4 tons of grain for one ton of lubricants and/or fuel. The reason why producers agree to barter is that payments for grain that is sold are usually delayed. Farmers do not have the funds to spend on the fuel, spare parts, and fertilizers they need each crop cycle.

Prices for products sold to the State are defined by Government Decree and in 1995-96 were supported by letters of credit at banks working through the grain companies that won the tender. Loans are usually dispensed in two parts and are meant to supply funds and equipment to producers who made a contract to supply state funds with grain. However, due to the late terms of loans (July and September), discounting, unfavorable weather conditions, and low yields, the advantages of this system have not been apparent, and farmers have refused to participate in the program.

The other channel to determine grain prices is through the Kazakhstan International Agroindustrial Exchange. Farmers do not go to the exchange directly because of lack of equipment for grain processing and storage. Besides, there are ways of marketing where prices are defined directly by the buyer and the seller. The marketability of grain is low and tends to get still lower. If in 1991 it was 58%, in 1996 it is 46%. Most grain produced is used on the farm as seed and fodder.

A poorly functioning financial mechanism, plus a low level of revolving funds on the farms resulted in the use of grain as payment for labor. The amount of such payment increases and reduces the effectiveness of grain production due to low prices, which are practically equal to production costs. The producer must have a wide choice of options for selling the grain so that he may choose the one most profitable for him.

In 1996, out of a total 3,523 mln t of wheat that was marketed, 0.795 mln t (23%) were sold to the state, 1,687 mln t (48%) were bartered, 0.469 mln t (13%) were sold directly to individuals through the catering system or as a salary substitute, and 0.074 mln t (2%) were sold through markets, exchanges, and auctions; the remaining 0.497 mln t (14%) is unknown.

Purchase prices on the free market were the highest: 3% higher than the exchange price, 7.4% higher than the state price; more than 10% higher than consumer cooperative prices and barter exchange, and 26% higher than direct sales (as a salary substitute and through catering). If all the wheat in 1996 had been sold at the free market price, that is, 8,725 tenge per ton, producers would have received 3,051 million extra tenge, for a total of 43 million dollars.

A special state agency should be established to determine grain policy in the country. This agency would know the economic situation and have special instruments to support grain producing farms and to regulate the grain market. This is the basis of food security in a country. Grain production should be especially protected.

Product distribution as an economic category means that the product should be distributed among the agents participating in its production, that is among the owners of production means. This depends on property distribution in the society. In a market economy, product distribution is regulated through the price, and its level depends on the development of the market.

Kazakstan's grain market is far from perfect due to the fact that the labor, land, and money markets have not been properly developed. The total crisis of the economy has caused high unemployment due to which a villager cannot profitably sell his labor.

The land market is not developed either. Due to the formal distribution of land among peasants and their lack of equipment, rural workers do not consider the land a treasure and often give it away free or transfer its ownership to the director of an enterprise.

All this proves that distribution of public agricultural products is not carried out fairly. The issue of storing sufficient grain to achieve national food security and establishing reserves necessary for the international market has to be urgently addressed. FAO recommends that this amount should be 17% of the yearly requirements of all types of cereals. However, the United States, having analyzed the situation of the grain market, came to the conclusion that grain reserves should be 40% of total production. Considering the instability of the

situation, the level of our reserves should be even higher. Research should be done to address this problem.

An association of producers, intermediaries, and suppliers should be organized as soon as possible to activate consumer demand and create a flexible system of linkages within the "production-consumption" network. A model grain market should combine the interests of all its participants backed by state policy oriented toward preserving independence of Kazakstan's grain production.

Grain Marketing in Kazakhstan

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Kazakhstan's successful transition to a market economy depends to large extent on reforms in the agricultural sector of the economy. Production of food and consumer goods made out of agricultural raw materials depends on the machine manufacturing industry, the chemical industry, sectors of the economy that process, transport, and store agricultural products, technical services, marketing, and supply. Development of an agricultural market economy is taking place at a time when the overall economy is in an extremely unfavorable situation. Several factors worsen the situation of the rural economy, such as the dramatic decrease in State financial support, price disparity for farm and industrial goods and services, decrease in the financial capacity of the population, aggravation of many problems of farm producers due to non-payment, partial or complete break-up of economic linkages among ex-USSR republics.

As a result of farm privatization, more than 47,000 agricultural production units, representing different types of property, were established. More than 90% of property is now non-state. Total farm production is over 18% of the GNP, over 21% of national income, in expenditures - 12% of total volume of national economy, and in agroindustrial complex - over 52%. The leading farm sector of Kazakhstan's economy is grain production (first of all, hard and

durum wheat varieties). The share of cereals in total arable area is 66%, including 43% to superior quality bread and durum wheat varieties. Grain production accounts for 33% of total farm production and for 70% of crop production. In some regions its share is even higher. For instance, in the North-Kazakhstan region it is respectively 55 and 90%, and in the Kostanay region, 50 and 86%. The share of wheat grain in agricultural exports was 65% in 1996.

There are great opportunities and resources for achieving efficient production in the country, especially of cereals. However, inefficient economic mechanisms during the transition period destabilized agricultural development; agricultural production continues to decrease, and there are still losses during storage, processing, and transportation. In 1996 the cultivated area in the country decreased by 18.5% compared to 1991; for cereals and legumes - by 19.1%; for wheat - by 10.8%. Input use in agricultural production also decreased. The biological yield potential of cereals, including hard and durum wheat varieties, is not realized.

Due to the dramatic decrease in application of organic and mineral fertilizers, soil fertility has diminished. Research demonstrated that soil under cereals annually loses from 0.5 to 1 t of humus per hectare. In 1996 the application of mineral fertilizers was 2.2% as compared to

1991; organic fertilizers - 4.8%. Fertilizer application for wheat decreased 32.2 times (most farms did not apply fertilizers at all). Around 16 mln ha are phosphorus deficient and 75% of arable lands have low humus content.

Due to the lack of financial resources, the supply of gasoline and motor oil as well as agricultural machinery deteriorated. By some estimates only 60-70% of the demand for combine harvesters and other agricultural machinery is satisfied, and optimal dates for field operations are not observed (research and practice have shown that cereal harvesting should be completed in 10-12 days; otherwise yield losses can reach 30%). Seed production has been almost non-existent in the last few years. The farming system has suffered considerably in all regions of the country. This naturally was reflected in reduced cereal yields and production.

Analyses show that if the cereals production system is observed, agricultural enterprises obtain high yields and profit. For instance, in 1996 the farms of Kostanay district (Kostanay region) obtained an average yield of 1.37 t/ha on an area of 192,000 ha; profitability was 34.2%. At the same time the experimental farm Zarechnoye obtained yields of 2.04 t/ha, and profitability exceeded 104%. Despite this fact, grain exports in 1995-96 decreased by 25%, from 3.9 mln t to 2.9 mln t. The contribution of

Kazakstan to wheat exports by the former USSR has sometimes reached 80%, and the cheapest grain was produced in Kazakstan.

The potential export market for the grain produced in Kazakstan is the CIS countries, China, Pakistan, Iran, and Mongolia. Satisfying the demands of this market requires a sharp increase in production of superior quality wheat grain. Potentially 5-7 mln t of grain can be exported, including 3.3-4 mln t of hard wheat. The cost of grain production has increased tremendously as a result of price liberation, decrease of grain production, break-up of linkages among the different branches of the economy, a dramatic increase of prices for energy supplies and other industrial products, and a sharp increase of sinking funds due to the reevaluation of fixed capital, inflation, and other destabilizing factors. The cost structure changed as well: the share of salary, seeds, and fertilizer decreased and, conversely, the cost of oil products, electricity, and credit increased.

There is no definite price policy except price liberation (introduced in 1993 for farm production and in 1992 for other goods and services), which has had negative effects on grain production. There is no methodology for predicting price changes (as there is in developed countries) and in recent years prices have not been predicted. This is the reason for faults in price regulations. Another reason is shortage of government funds to stabilize grain production.

A major criterion for balancing economic relations is equity of exchange between agriculture and

other branches of the economy or price parity, which can be calculated easily. The year 1990 was accepted in Kazakstan as the baseline for price parity. At that time farmers could buy the amount of resources needed for production with one unit of production sold (the ratio of the price index for agricultural production sold and the price index for industrial goods and services equals one).

The analysis showed that the price parity index in 1996 was 0.07, which means that growth of industrial prices is 11.6 times higher than that of farm prices. For instance, in 1996 the price for electricity increased 4087 times compared to the price in 1992; for wheat grain the increase was 449 times. Another example – in 1996 the purchase of a combine harvester ENISEY was equal to 900 t of grain, DON 1500 – 1200 t, John Deere – 1650 t which is 40% higher than in 1995. Grain prices are lower than on the world market but the prices of energy and other industrial products have reached world prices. Average price of grain in Kazakstan was 7472 tenge, which is equal to \$100; at the same time similar grain is bought from a US farmer for \$175.

When the prices of bread and durum wheat became equal, there was a four-fold decrease in durum wheat area and 20 times decrease in the sale of durum wheat grain. This, in our opinion, resulted from the fact that wheat prices in Kazakstan were set without considering quality. For instance, the price of a wheat variety with superior grain quality and gluten content higher than 36% (1st class) was 1.8 times lower than scientifically recommended prices and 1.6 times lower than prices in other countries. Wheat grain with 32-

35% gluten content (2nd class), was 1.8 and 1.2 times lower. The numbers are similar for durum wheat: 1st class with 28% gluten content and higher – 70% and 2 times lower. This approach to determining wheat grain prices reduced farmers' incentives to grow superior quality varieties.

Due to considerable reductions in wheat price incentives, the quality of wheat grain deteriorated dramatically during 1992-96. In 1986-1991 the average gluten content in wheat grain was 28-32% and average price index was 1.75-2.29; in 1992-1996 the gluten content was 20.8-23.7, and the average price index was 1.11-1.30.

Several criteria are used in wheat exporting countries to evaluate grain quality. In the USA, for instance, the criteria are protein content, test weight, and percentage of mixture, while Germany and the CIS countries use gluten content and 25 other traits (Table 1).

For Kazakstan the grain market represents an independent economic system which at present is poorly if at all managed by the government. This is why additional profit from grain sales remains in the hands of intermediary organizations that buy and sell and of wholesale and retail enterprises. Price increases due to these manipulations may rise 40-50% over the wholesale price. As a result the share of wheat bartered in 1996 was 76% of total wheat grain, 79% of durum wheat and 87% of superior quality wheat.

The State Food Contract Corporations responsible for moving grain from producer to consumer are unsatisfactory. For instance, bills of

exchange did not affect agricultural production because they were not backed financially (low price and lack of credit). The first issue of the bills of exchange amounting to 68 mln tenge was made on July 1, 1996; the second on September 1. However, to provide producers with funds for oil and other resources, they should have been issued in January. Only \$70 mln were paid for the credit from \$140-150 mln initially allocated. The producers had to pay extra for the credit, which could reach 10% depending on the date the credit was paid back. This resulted in low producer prices while selling wheat to the government: \$80-90 per metric ton. The deficiencies in the economic mechanism during the transition period made grain production unprofitable. To give an example, the profitability of grain production in 1990 was 150% and only 1.7% in 1996.

Most producers lack operational funds. In 1996 each agricultural enterprise received on average 1000 money units of support from the government, which is extremely low. Capital investment in agriculture in 1996 was 4.4% of the total amount invested in the country, compared to 39.8% in 1991.

Proposals

To improve the efficiency of cereal production in Kazakhstan, high input production technologies should be introduced. They will allow farmers to increase yields by 0.5 t/ha and obtain an additional 2400-2600 tenge/ha (Table 2). To reduce grain production costs, farmers need high efficiency machinery, state subsidies for seed production, partial compensation for the cost of mineral fertilizers and pesticides, tax discounts, and lower interest rates.

World grain prices are based on supply and demand and are, to a certain extent, regulated by international agreements between exporters and importers. In reality prices are dictated by the USA in agreement with Canada. Because of this, uniform quality standards are necessary to determine the price of wheat, and in CIS countries, a uniform approach to price setting (taxes, duties, etc.) is needed.

The disparity between prices of farm and industrial products causes an imbalance in the commodity exchange between the farm and industrial sectors: production of goods targeted to agriculture decreases, and agricultural resources diminish. Such interdependence results in degradation of the country. So the most important indicator of grain production is reestablishment of price parity between agricultural and industrial products. Its quantitative parameter should be the increase of farmers' purchasing power based on unit of production sold.

As the experience in countries with developed market economies demonstrates, domestic grain markets depend to a large extent on price controls imposed by the government (guaranteed, credit and other prices). Guaranteed prices provide insurance from the government for farmers' profits. The government uses guaranteed prices to buy grain in situations where average market prices are lower than the guaranteed price as well as to sell grain directly to the state or as an index of market prices.

Special target prices should be determined annually by the Ministry of Agriculture. They should be used as the basis for providing a parity price

Table 1. Main quality parameters used in the USA and in Kazakhstan.

Parameter	Country	Quality Group					
		Superior	1	2	3	4	5
Protein content, %	USA	-	11.5	11.0	10.5	9.5	8.5
	Kazakhstan	16.0	14.7	14.0	13.5	11.0	<11
Gluten content, %	USA	-	-	-	-	-	-
	Kazakhstan	36	32	28	23	18	<18
Test weight, kg/hl	USA	-	747	734	708	682	644
	Kazakhstan	750	750	710	710	-	-
Weed mixture, %	USA	-	0.5	1	2	3	5
	Kazakhstan	1	1	1	1	1	1
Grain mixture, %	USA	-	3	5	10	10	10
	Kazakhstan	2	2	2	2	2	2

Table 2. Efficiency of modern cereal production technologies in Kazakhstan.

Technology components	Yield increase (t/ha)	Additional cost per ha (tenge)	Price of the yield increase per ha (tenge)	Economic efficiency per ha (tenge)
Fertilizer	0.21	1335	2205	870
New varieties	0.11	785	1155	370
Observation	0.02	130	210	80
Crop protection	0.15	450	1,575	1,125
Total	0.90	2,700	5,145	2,445

ratio for industrial and agricultural products, taxes and profits for grain production in the future. Special target prices can also be used to define guaranteed and security rates, and to estimate state subsidies and compensations. Since intermediaries may raise prices by 25-30%, the state should regulate this based on real costs.

The marketing system that should be introduced has to influence the activity of producers, take into account producers' industrial and economic interests, and reduce the price of services. Thus, in developing mechanisms for regulating grain prices, equivalent prices and the price disparity for industrial products have to be determined, as well as the losses to grain producers due to the price disparity; the amount and source of compensation for farmers' financial losses also have to be determined. In defining a methodology for setting grain prices, the peculiarities of market development should be taken into account, as well as its structure, which should reflect grain purchases for the state, sale on the exchange and the free market.

It seems logical to establish a special government agency that would determine the grain production strategy for the country and that would have real power to support and regulate the grain market. It is necessary to maintain certain grain reserves to guarantee Kazakhstan's role on the world market (in the USA such reserves account for 40% of annual production). There is a need to develop a marketing service to study the supply and demand, world market prices and CIS prices. This service should be established on a uniform methodological and technical basis.

The basis of marketing activities should be the business plan of enterprises that includes a marketing plan. The latter defines the demand and the market capacity, competition, sales strategy, price setting, advertisements, etc., as well as a financial plan showing the balance of costs and benefits. At the enterprise level the introduction of marketing activities is carried out gradually in five stages. At the first stage the possibility of introducing a product into the market is studied using advertising. At the second stage a broader approach is developed based on a plan whose major objective is consumer satisfaction with the product and after sale service. At the third stage the production and quality of the product gradually improves. At the fourth stage the enterprise studies its own and the competitors possibility to occupy certain stable niche in the market. Meanwhile a strategy is developed to capture some segments of the market better than competitors. The fifth stage includes analysis of market and demands, planning, accounting, and work regulation connected with the markets.

The peculiarities of grain production and sales affect the marketing mechanism, which depends on the following factors:

- study the status and dynamics of the demand and use the data in making decisions regarding production;
- maximum adaptation of production to market demand in order to increase profitability of the enterprise, demonstrate market impact and the demand for its product using advertising.

The principles of marketing define its functions, which reflect the features of agricultural production and sales. The following should be taken into account: planning activities taking into consideration the possibility of achieving practical results; concentrating research, design, production and sales in one operation to increase marketing impact.

The marketing system includes: identification of existing and potential consumer demand for agricultural goods and services using a detailed study of the market and perspectives of its development; development of packaging; organization of services; the choice of special advertising methods and sales stimulation; organization and improvement of methods of product sales, development of different products; coordination and planning of production; development of the price system; evaluation of its efficiency and adjustment if necessary; development of research improving the production and the quality of the product; analysis of the economic efficiency of the use of resources and materials; organization of the interaction with suppliers and evaluation of their reliability; establishment of marketing and its management.

A marketing plan represents the whole system of activities and contracts, and determines the development of production in the future.

Seed Production in Kazakhstan

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A lot has been said about producing and breeding wheat, a favorite crop of Kazakhstan farmers. They work hard and apply wheat cropping technologies. The key task for the future is to improve spring wheat farming technologies. In my paper I would like to discuss issues of wheat seed production.

First, the seed production system in Kazakhstan is a comprehensive network of seed production enterprises situated across the country in different climatic zones. Seed production of maize for grain, sorghum, cotton, and sugar beet is established in southern Kazakhstan; seed of oil crops is produced in the east, and cereals and wheat, in the areas where they are sown. Winter wheat seed production is organized in the southern and western parts of the country, and spring wheat seed production is localized in the north.

The seed production system in our country comprises the state system of variety testing, parental lines seed production, industrial seed production, system of state insurance stock and state seed control. In addition, there are auxiliary services, such as pest, disease and weed control, and plant quarantine. All the auxiliary services report to the Ministry of Agriculture. The Ministry's Department of Food Production Technology is in charge of seed production, and within it there is a subdivision that produces seed of agricultural crops.

I want to emphasize the fact that we have managed to preserve the seed production system in general, and wheat seed production in particular, during the transition to a market economy. At present the system comprises 38 research institutions, 2 breeding centers, 76 variety testing sites and 6 stations, 177 seed inspection services and 65 elite seed production farms. Further seed multiplication is done on 375 seed production farms. The work is coordinated by the Ministry of Agriculture.

Seed production starts with varietal testing. It is conducted on 82 variety testing sites and stations. After three years of testing, the Regional Variety Testing Commission suggests varieties for release. Data from different regions are concentrated and analyzed by the National Variety Testing Commission. After this by decree of the Minister of Agriculture a commission is established that considers and approves changes in the list of varieties to be released. This commission includes experts from the Ministry of Agriculture, research institutions, and the leading breeders in the country. Based on recommendations by the Commission, the Minister issues a decree on the changes in the variety release list and the breeders obtain the patents.

It is practically impossible to release a variety that has not been properly tested. A recommended variety must yield at least 0.3 t more than the check variety and must also have good quality, plus resistance to pests, diseases and lodging. In 1996, there were 120 cereal varieties released in the Republic including 69 wheat varieties, 31 of which were developed in Kazakhstan.

In 1997, 102 spring wheat varieties (53 bred in Kazakhstan) were tested at 51 testing sites covering all soil and climatic zones in the Republic. Twelve spring wheat varieties were submitted to the State Variety Testing Commission by Kazak breeders this year. Eight of them were included in variety testing experiments; four were not included due to lack of seeds. A limited amount of seeds of new varieties often delays testing and some ecological zones are not included.

The testing of wheat varieties from CIS countries faces financial constraints because we must pay for the seeds in hard currency and organize their transportation. In 1997, 48 spring wheat varieties were officially released in Kazakhstan, including 39 bread wheat and 9 durum wheat varieties; 23 varieties were developed in Kazakhstan; 30 were classified as superior quality (strong) wheat and 7 as valuable quality wheat.

Recently released spring wheat varieties are characterized by high yield potential and lodging and drought resistance. Belonging to different maturity groups and having superior bread making quality, these varieties are: Damsinskaya 90, Kazakstanskaya 25, Karabalikskaya 90, Karabalikskaya 92, Lutescens 32, Lutescens 90, Pamyat 47, Tselinnaya 3c, Akmola 2, Kenjegali, and Nauriz 2.

In the Northern regions spring wheat variety Kazakstanskaya rannepelaya performs well. Its yield potential is 0.4 t/ha higher than Saratovskaya 29. It has been released in Kokshetau, Northern Kazakstan and Kostanay regions of Kazakstan and in Chelyabinsk region of Russia. Yield of variety Kazakstanskaya 25 is 0.4 t/ha higher than the check and it matures 1-6 days earlier. The yield of Karabalikskaya 90 is 0.5 t/ha higher than Saratovskaya 29. Breeders should advertise their varieties by informing grain producers, farmers and other associations in the Republic.

Kazakstan farmers are actively using varieties from other countries. Producers collaborate with research institutions in Siberia, South East of European part of Russia. The following varieties are adapted to our conditions: Omskaya 19, Saratovskaya 42, Saratovskaya 55, Bezostaya 1 and others.

In total 25% of the wheat area is sown to locally developed varieties; of these 75% were developed in the CIS. The total number of varieties officially released is 70 including 32 varieties developed locally and 38 from the CIS countries. However, only 48 varieties

are actually used for production including 23 locally developed and 25 from CIS countries.

The state system of variety testing is being reformed. Variety testing sites and stations are being transferred to a self financing system. Six state variety testing stations and 76 crop testing sites have become independent entities and were granted 300-500 hectares of rainfed land or 50-80 hectares of irrigated land by the state.

Self-financed variety testing sites and stations are highly effective experimental production enterprises due to their highly skilled staff, good crop rotations and overall good level of farming. They are involved both in variety testing and seed reproduction of the new varieties. Breeder's seed is produced in several sites and stations on a contract basis with the breeders. That is why the state variety testing sites are included in a network of elite seed production farms. This should accelerate the production of seeds of newly released cereal varieties. The system produced 4588 t of elite seeds in 1996.

In total 63 seed farms are engaged in elite seed production in Kazakstan. Farmers need to produce 27,000 t of elite seed to replace old seeds. However, only 25,000 t of elite seed were sold for planting last year. Farms under different forms of property ownership produce and market elite seeds. Private farms have started producing elite seed too. For instance, private seed producing farms "Panfilovskiy" in the Pavlodar region and "Turgen" in the Almaty

region, working in close contact with research institutions, sold 306 and 500 t of elite seeds, respectively.

Based on the seed production scheme, elite seed production farms deliver elite wheat seed to 316 seed producing farms situated in different areas of the Republic. In addition, big farms grow elite seeds themselves on 0.8-1% of the sown area. Area devoted to seed production occupies 20% of total wheat area. Total replacement of the seed of a variety is done once every five years. The fifth seed multiplication is the last one used for production. In total, seed production farms sold 230,000 t of seed for the 1997 crop. Production farms receiving seeds of the first and second multiplication continue to reproduce them in their seed production departments.

By suggestion of the Ministry of Agriculture, an elite seed reserve is being established to provide a seed exchange and supply seed to farms that have suffered unfavorable weather conditions. Seed production farms are the source of seeds. In some years up to 1 mln t of seeds were processed and sold in the Republic. In 1997 the state reserve accounted for 85,000 t of certified seed. Farms that experienced drought received 270,000 t of seeds.

This year the state plans to buy 20,000 tons of certified wheat seed. In addition, all farms in the Republic will establish their own seed reserves. Elite seed production farms put into reserve 100% of the elite seed needed for the farm, and regular seed production farms store 15% of their demand for elite seed.

Seed quality control in Kazakhstan is exercised by the State Seed Inspection Board and its network of local agencies. State inspectors and research institute representatives inspect and approve seed fields. In 1997 they covered 3 mln ha. According to Seed State Inspection Board data, out of 994,000 t of spring wheat seed used for planting in 1997, only 23% met the requirements of the First Grade of the seed standard, 38% - of the Second Grade and 39% of the Third Grade. More than 98% of the wheat area was planted with certified seed, including 61% sown with seed of the first and second multiplication and 39% of third-fifth multiplication. Imported seed is inspected by the State Quarantine Inspection Board.

Seed quality depends on the infrastructure and machinery used for seed production. There are 15 complexes in Kazakhstan that engage in large-scale seed processing and storage. There are 6100 threshing floors, 320 electromagnetic machines of EVS 1A type, 247 of Petkus Selectr and Petkus Giant type, 1635 cleaning machines OS-4.5, SM-4 and 2333 seed treatment units. Thus, enough machines and asphalt sites are available for seed production. However, the new owners will have to rebuild storage facilities and renew the machinery.

Seed quality also depends on the level of farming. For seed production we use seed of the first and second multiplication, and the first and second classes of seed of released varieties. Seeds are grown in 3- or 4-field rotations and normally after fallow. During the vegetative period fields are subjected to the necessary tillage and treatment. Swath harvesting is applied. After

harvesting seeds are cleaned and screened by special machines with graders and then stored at an average moisture content not exceeding 14%. All farms maintain special documentation on spring wheat seed production. The State Seed Inspection Board controls all technical operations related to seed production.

To improve the seed production system and its management, we have started cooperating with the National Academic Center for Agricultural Research, R.V. Williams Kazak Agricultural Research Institute, A.I. Baraev Kazak Institute of Cereal Production and other institutions dealing with seed. Together we are developing a new scheme for seed renewal and setting up a network of elite and regular seed production farms.

We have started introducing economic methods of management. The State Foundation for Support of Agriculture has been established to provide subsidies that allow elite seed production farms to reduce prices of elite seed. This proposal was put forward by the National Academic Center of Agricultural Research. In 1996 for the first time, elite seed production farms received the total amount of money for the seed they sold in 1995: 204 million tenge. This year we are paying for the elite seed marketed in 1996. One ton of elite seeds is cheaper by 7000 tenge which constitutes 35% of its price.

To stimulate seed production we pay bonuses. Thus, the bonus for elite seed is 150% of the sale price for third class bread wheat, 80% for seed of the 1st multiplication that meets the

requirements for the first category of variety purity and the first class seed; 70% for seed of II-IV multiplication for the first category and first class, and 60% for seed of I-V multiplication for the first category and second class. Considering that many farms are short of funds, barter is recommended as a form of payment between producers and consumers.

Presently we are improving the management structure. We are planning to establish the National Association of Agricultural Seed Producers with the participation of seed producers, research institutions and trade associations in different regions of Kazakhstan. Such associations have already been established in three regions and six regions are working on their creation. After establishing the regional structure, we will create national governing bodies. This organization should be established on a voluntary basis and it will fulfill the will of its members, seed producers and other stakeholders. This network will bring together the efforts of all those working in this field. If there are interesting proposals from the private sector, we are willing to discuss them.

Seed production is an important part of agriculture, and we are trying to stabilize it. Among many approaches there is cooperation with foreign companies. We have some experience collaborating with Yugoslavia, Moldova, Ukraine, Russia, France and Germany. At present we are testing 130 crop varieties from 10 countries. Foreign varieties are tested on a contract basis. We could consider introducing foreign varieties. There are other

options as well. We suggest that foreign companies finance seed production of local varieties using local technologies under mutually beneficial terms.

We will continue to improve the system of variety testing and strengthen relations between elite seed production, variety testing and industrial seed production. This will help to reduce the time needed for introducing new varieties. If our guests have any suggestions concerning variety testing, we are willing to discuss them.

We are working to create a legal basis for seed production. We have prepared a Draft Law "On Protection of Plant Breeding Achievements" and "On Seeds". The drafts provide an integrated state policy on seed production. They contain suggestions on strengthening of state support to seed producers.

The system of state seed quality control will be further improved. Permission to reproduce, market and use seed will be granted only to persons and companies having production facilities and meeting state testing requirements. They will

be included in the State Register of seed producers. Those who do not have such permission will be able to grow seeds for their own use but will not have the right to sell or exchange them. This will apply to all Kazakhstan territory and cover all entities, including foreign firms engaged in production, storage, sale and use of seed.

We are open to cooperation with all those who wish to invest in joint seed production. We are sure that this will enable us to maintain and improve the quality of hard and durum wheat varieties produced in Kazakhstan and known all over the world.

Farmers' Views on Production Problems, Marketing Issues, and Technology Transfer

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After working for many years as the director general of an agricultural enterprise, I am convinced that successful spring wheat production depends on the interaction between producers and scientists. Farmers in the Akmola Region are lucky to have the A.I. Baraev Institute of Cereal Production. Taking my farm as an example, I would like to demonstrate the impact of the new agronomic methods and the effect of the science-producer relationship on wheat yields.

Thirty years have passed since I started working in grain production, basically all my career as a director. The ratio between minimum and maximum yield reflects the influence of science, farming practices and the environment on yield increase. In 1963 for example, our farm obtained wheat yield of 0.19 t/ha due to severe drought. The following year 1964 was very favorable and we harvested 1.4 t/ha. At that time there was no scientific approach to wheat cultivation and there was no connection with the Institute – we did what we thought we should. So the ratio between minimum and maximum yield was 7.7 (1.4 : 0.19). In the last decade the minimum yield we observed was 1.6 t/ha and the maximum was 3.7 t/ha, harvested in 1992. The ratio is 2.1. I think it is clear

how science can contribute to spring wheat production. As you can see the minimum wheat production increased more than eight times. This clearly demonstrates that yield increases are a result of joint efforts by scientists, agriculturalists and farmers.

Today everybody knows that the soil conserving system of farming developed by scientists at the A.I. Baraev Institute of Cereal Production based on the application of new machinery that maintains the stubble was the major factor contributing to yield stability even during very dry years. To give an example, I would like to provide yield data for the Vishnevsk District of the Akmola Region (Table 1).

This year we estimate the yield on our farm to be 1.7 t/ha; the district average is about 0.7 t/ha. This example clearly demonstrates that Kazakstan farmers have good resources provided there is a cooperation with science. On the other hand, the recommendations of the A.I. Baraev Institute of Cereal

Production are difficult to implement given current prices for fertilizers, herbicides, chemicals for seed treatment, and farm machinery. The disparity in prices of agricultural and industrial products means that most farmers are not able to apply fertilizers at all. They do not buy tractors and combine harvesters. Fuel and oil prices are very high as are the costs of spare parts and electricity. This is why we now see fallow fields that were not cultivated, fields after wheat that were not plowed, and a lot of weeds in the fields.

A few personal observations: one cannot cheat the land. In order to annually obtain a good harvest, it is necessary to plow in the autumn, conduct snow accumulation twice in winter, till for moisture conservation and prepare the soil for planting in spring, plant in moist soil, plant good quality seeds of released varieties, cultivate the fallow in summer, take care of the crop in summer, and harvest in the shortest period possible. In this way one will obtain good yield every year.

Table 1. Yield (t/ha) of spring wheat in different farms of Vishnevsk District, Akmola Region.

Farm	1991	1992	1993	1994	1995	1996
District average	0.64	1.58	1.09	0.68	0.82	1.01
Izhevskiy	1.92	3.60	1.70	1.67	1.65	2.44
Volgodonovka	0.37	-	0.77	-	0.57	0.67
Beloyarka	-	1.08	-	0.44	0.47	0.41

Research Structure Improvement and Human Resources Development

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National Academic Center of Agricultural Research

Almaty, Kazakstan

The Republic of Kazakstan is situated in the middle of the Eurasian continent and occupies 2 million 275 thousand square kilometers. From north to south, it stretches from the temperate humid forest steppes in western Siberia to the deserts of Central Asia and, from west to east, it spans from the Volga River to the peaks of the Altay Mountains.

This vast territory is a unique natural laboratory that includes every type of landscape in the world, as well as a wide variety of natural, climatic and soil environments, which defines the structure of agricultural research. The main objective of agricultural research in Kazakstan is to help achieve national food security. Without food security it is difficult to address economic and social objectives, participate in the process occurring in the world and provide for national security.

Grain production is the basis of food security and agricultural economy of the country. Cereals are not just a food item for our country but an important strategic commodity. Bioclimatic, research and staff potential plus soil and climatic conditions make it possible to grow cereals on 17-18 mln ha and produce enough high quality grain not only to meet domestic demand but to export to neighboring countries.

Kazakstan was an important grain producer in the former Soviet Union; three quarters of its production was exported to meet the demands of the other USSR republics. Kazakstan was not known to the world as a grain-producing country because the Soviet Union also purchased huge amounts of grain abroad.

The situation has changed, and Kazakstan now sells its grain on the international market. Not only our nearest neighbors and the traditional consumers of our grain – Russia, the countries of Central Asia and the Caucasus - are interested in Kazakstan grain but other foreign countries too. As a result, we are focusing on strengthening our research capacity and developing grain production as a way of ensuring Kazakstan a solid position in the world grain market.

In 1993 the government of Kazakstan defined a plan for developing the agricultural production complex as a whole. Due to the changes in land tenure and means of production, major changes occurred in the agricultural sector, giving farmers freedom in production and marketing of commodities. Now they are free to define their production structure. The area sown to crops diminished because cereals are no longer sown on less fertile lands where yields are low. Instead of

significant growth in yields and in the amount of grain harvested, as predicted in the 1993-95 plan, considerable decreases in production occurred due to the fact that grain producers were in the process of adapting to the new conditions. At present further optimization of the structure of cultivated areas is underway. Private investors have started actively investing in grain production. Beginning in 1996 a positive trend in grain production growth appeared and is expected to continue this year.

Grain production in Kazakstan should continue to develop dynamically. To implement this, agricultural researchers need to develop a strategy for improving grain production in the near future, considering changes in the agricultural production complex. Due to the orientation of Kazakstan to international markets, research on marketing, price and market formation, storage and sales is essential.

Under existing energy, machinery, fertilizer and plant protection chemical prices, production is profitable if yield is not less than 1 t/ha. In such conditions it is necessary to seek more effective ways to increase yields and total grain production.

Scientists at the Kostanay Research Institute found that if land use does not follow the agronomy, spring wheat varieties grown in the region yield 0.8-0.9 t/ha. Using the optimal cultivated area structure and scientifically based crop rotations, the same varieties produce yields of 1.7-1.8 t/ha. New, high-input varieties yield 2.5 t/ha and more. Thanks to agronomic research conducted at the Institute's "Zarechnoye" experiment station, yields of 2.67 t/ha; 1.5 t/ha and 2.05 t/ha, respectively, were obtained in favorable 1994, very dry 1995, and 1996, a year with intermediate precipitation. This is 2 or 3 times more than the productivity of other farms in the same area. This year we obtained 3 t/ha. We can give similar examples for other experiment stations of the National Academic Center of Agricultural Research. Analyzing the available data and comparing them with data on regional and national productivity, we come to the conclusion that efforts aimed at achieving sustainable grain production under the new economic conditions should start with establishing an optimal structure of cultivated areas, farming systems, and crop technologies that would provide for dynamic increases in cereal productivity. It is essential to develop new farming systems considering soil, climatic and landscape conditions of individual farms and agricultural associations.

Experience shows that 35-50% of increases in agricultural production is due to the variety and high quality seed. For the vast territories in Kazakstan, which comprise 60

agroecological zones, quite a large assortment of cereal crop varieties with high yield potential and good stress resistance is needed.

New agricultural associations place high demands on crop varieties and hybrids under development, in accordance with world standards. These varieties should be highly productive, adaptable to local conditions, and pest and disease resistant. This problem seems to be possible through the use of plant genetic resources in the breeding process. Considering this a technical research program "Genetic Resources of Crops, Animals, Microorganisms, and Their Effective Use in the Agricultural Production Complex" was developed. The program includes conservation and rational use of genetic resources, first of all those available in Kazakstan's research institutions. It will manage the conservation, evaluation, documentation and use of genetic diversity adapted to local conditions. In northern Kazakstan, the A.I. Baraev Kazak Institute of Cereal Production is responsible for this work. In the south this work will be supervised by the R.V. Villiams Kazak Agricultural Research Institute. Special departments dealing with genetic resources with qualified staff have been established there.

To enrich their collections, our research institutions exchange seed with IRRI (Philippines), Japanese International Center for Plant Genetic Resources (Osapo), CIMMYT, ICARDA, Russian Institute of Crop Production (St. Petersburg),

International Center for Winter Wheat Breeding (Isbridge, England), Institute of Genetic Resources (China), "Dobrudja" Institute of Sunflower and Wheat (Bulgaria, Tolbukhino), Yugoslavian Maize Institute "Zemun Pole" (Belgrade), Bulgarian Maize Institute (Kniazhi) and other institutions all over the world.

Very high priority is given to breeding work in our Republic mobilizing the world and local genetic resources. Breeding is conducted at 38 research institutes on 170 crops, though they do not get enough funding from the national budget. Wide use of genetic resources has allowed breeders to develop and release more than 200 new crop varieties and hybrids. In total, 1000 varieties and hybrids have been released in Kazakstan, and 1800 varieties are under state variety testing at present. Varieties developed in Kazakstan occupy 20% of cultivated areas. A lot should be done to multiply and release already developed varieties.

Breeders at the R.V. Villiams Kazak Agricultural Research Institute and Krasnovodopadskaya Experiment Station; Aktiubinsk State Experiment Station; Eastern Kazakstan Research Institute of Agriculture; A.I. Baraev Kazak Institute of Cereal Production, Pavlodar and Karagandy Research Institutes of Agriculture and Karabalyk Experiment Station are engaged in breeding in southeastern, western, eastern, and northern Kazakstan, respectively.

In the south and southeast breeding efforts are directed towards developing winter wheat varieties for rainfed and irrigated conditions. Research objectives were defined accordingly. For rainfed conditions breeding is directed towards the development of drought-resistant, winter-hardy varieties with yield potential of 3 t/ha and improved technological and baking qualities. For irrigated conditions breeding is directed towards developing high-input winter wheat varieties with grain yield of 10 t/ha and higher. Together with quality characteristics, special attention should be paid to bunt resistant varieties in the south and southeast. These questions should be considered in a program of collaborative research.

In spring wheat breeding the following traits are important: maturity, drought resistance, high productivity, tolerance to low

temperatures in spring and fall, and high grain quality. Special attention should also be paid to the development of varieties resistant to septoria leaf blight, powdery mildew, rusts, root rot and other diseases.

In our opinion, these problems can be solved by combining conventional breeding with biotechnology, biological engineering and multidisciplinary research with biochemists, technologists, immunologists and other experts. Many of them talked here at the conference and we think it is necessary to consider their suggestions when developing collaborative research programs. Practice has confirmed the need for genetic resources exchange to further improve breeding and seed production work. This is directed towards developing research and practical links between NACAR and CIMMYT.

The Republic has a network of research institutions, highly skilled personnel, enthusiasts and relatively good infrastructure and equipment. In spite of the difficulties of the transition period, agricultural researchers are trying hard to keep the traditions in research and create the basis for future research. The solution of many problems both in farming and breeding is blocked by the lack of financial resources. We think that in collaborative projects these weak points of ours will be considered.

We believe it is important to educate our students in US universities and at your center. It is a pleasure to see young researchers who were trained at CIMMYT and ICARDA, and who are now fruitfully working in our research institutions. They helped a lot in preparing and holding this conference. We are thankful to you for this and wish there were more of them.

Developing a Research and Training Structure

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Research is very important for developing and reforming agricultural production in Kazakstan. Training highly qualified personnel should be done in close contact with research and production. This was taken into consideration when the conceptual approach to training agricultural specialists was defined by the Akmola Agricultural Institute. The Institute received the status of agricultural university in 1996 and is named after the famous writer and statesman Saken Seifullin. Our University, which celebrated its 40th anniversary in October 1997, is an important center of agricultural education.

The University has a highly qualified faculty made up of 400 members working in 42 departments. Among them are 18 professors and doctors of science, plus 146 assistant professors and candidates of sciences. Every third doctor of sciences and every second candidate of sciences obtained their degrees in our university. The university consists of 10 departments: agronomy, architecture, animal science, veterinary medicine, land management, agricultural mechanization, electrical engineering in agriculture, economics, pedagogy, and the humanities. It offers training in 18 specialties and 5 types of specialization. Instruction is in Russian and Kazak languages. The total number of students is about 7,000.

In total our University has trained 30,000 agricultural specialists. It is hard to find a field of activity in

Kazakstan's agricultural complex where there are no Akmola University graduates. Many of them have become directors of agricultural enterprises and coordinate the work of agricultural industrial complexes; others are talented researchers and teachers. All this is possible due to the integration of research and study. We assume that only instructors who are doing research can give good quality knowledge to the students; that is why the departments and chairs are actively engaged in research. The research addresses the important problems of agricultural production, and projects are chosen on a competitive basis.

The achievements of our researchers in soil fertility management, seed production of virus free potatoes, development of highly effective brucellosis and colibacteria diagnoses, vaccines for poultry production, breeding of a local type of Holstein cattle, and new types of sheep are widely known.

Kenzhegaly, a new spring wheat variety developed by the University's biotechnology center, yields 0.3-0.5 tons per ha more than the varieties grown in Northern Kazakstan. Wheat breeders of the agricultural university have submitted to the variety testing authority two more new spring wheat varieties, Dostyk and Lutescens 94.

Our economists are working on developing the methodological and

legislative basis for planning interfarm land use and selecting effective farming systems on the basis of privatized state farms.

The University has held several events: six university, national and international conferences were held here in the last three years. Agricultural researchers promote their work by publishing their results and broadcasting them on radio and television.

We have established fruitful partnerships with universities and research institutions in Russia, Germany, the USA and other countries. The main trends in cooperation are training of students, postgraduates and professors, joint research, participation in TACIS and TEMPUS programs, hiring highly qualified professors to give lectures, etc. For the last six years over 200 faculty members and students were trained at universities in the USA and Europe.

Last year the project "Development of Farming and Food Processing Industry in Akmola Region," initiated in 1994, was completed. The project was carried out by the University together with two companies: Agristudio (Italy) and Atkins (Great Britain). In collaboration with experts from the USDA Agricultural Marketing Service, we have developed a model system of agricultural commodity market information for the Akmola region. Project output is used for training and research, and

distributed to enterprises, farmers, and businesses. This is accomplished through the consulting center of TACIS.

The constant concern of the University President's office is the post-graduate courses that started in 1969. There will be 59 post-graduate students this year. At the University there are three councils that grant scientific degrees in the areas of crop science, land management and animal science. We are planning to organize two special regional councils for granting doctor degrees.

Currently the University trains specialists of a new kind. They have to be able to tackle extraordinary tasks with creativity, quickly estimate the situation and find ways to efficiently apply scientific ideas, new equipment, technologies and labor management. They should be able to evaluate the functioning of separate divisions, staff on the whole, each worker, and their own activity too. We train specialists for all branches of the agricultural industrial complex including production technology, storage, processing and marketing of agricultural products.

All the departments at present are revising their educational programs to meet modern requirements. The focus of training is now the student's personality, his or her individual characteristics and abilities, and development of creativity. The highest priority is given to increasing the quality of specialist training. This is the most important task at the present stage of economic reform. Many directors and specialists of agricultural enterprises have become the major obstacle in the transition to a market economy, private property, new forms of enterprises (cooperatives and joint

stock enterprises) as well as in the introduction of international and national research results.

A comprehensive program was developed to improve the economic knowledge of the specialists. Curricula have been changed. Students of all departments take courses in market economics, management, marketing, auditing, agribusiness, organization and functioning of enterprises with new forms of property. These problems are discussed in workshops during extension courses. We're paying more attention to continuous multi-level education. We realize that modern enterprises require a new type of managers who can organize the agricultural production process, consult the farmers, work on a farm as a leader or a staff member, be able to apply a socioeconomic test, predict the results of agricultural activity and the emerging trends in the production environment.

To further improve the qualifications of its faculty and researchers, the University has established agreements with research institutions in Kazakstan. The cooperation with A.I. Baraev Kazak Institute of Cereal Production has turned out to be very effective. In the course of reforming specialist training, the University will continue strengthening its international links with Russia, the United States, Germany, Britain, France and other foreign countries. We are planning to set up international exchange of graduate and post-graduate students, instructors and researchers.

In addition to the above mentioned areas of research, the University submits new projects for grants announced by the Ministries of

Science, Agriculture, Economy and Bioresources and the International Foundation for Independent States of the Former Soviet Union. A project proposed by Dr. Eserkepov has become a part of the program of the Institute of Space Research of the Ministry of Science-Academy of Sciences. Within this project our Geographic Information Center, together with the Institute of Space Research and A.I. Baraev Institute of Cereal Production, will take part in monitoring crops and forecasting grain yield using remote space monitoring and terrestrial observation. This work was included in astronaut Musabaev's scientific program during his long sojourn aboard the Mir Space Station.

The Israeli research center in Volcani is interested in joint research on developing a new technology for producing virus-free potatoes. To conduct this work a \$150,000 contract was signed in 1997. The University has become a member of interregional scientific production association "Kazakstan Elite Seeds," which was organized to improve the status of breeding and seed production in northern Kazakstan and neighboring regions of Russia. With the help of this association, the new wheat variety Kenzhegaly will be released in some regions of Kazakstan.

The University is developing its scientific links to the A.I. Baraev Institute of Cereal Production. We recently signed a bilateral agreement on scientific cooperation that will provide our students with the opportunity to accomplish practical studies at the Institute.

Appendix 1

Recommendations on Potential Areas of Collaboration

Work Group 1: Breeding, Genetics, Biotechnology, Crop Protection and Genetic Resources

Activities recommended for joint Kazakstan/CIMMYT programs:

a) Breeding spring bread wheat for Central and Northern Kazakstan with emphasis on:

- drought tolerance
- increased yield potential
- increased disease resistance (septoria, leaf rust)
- early maturity
- high bread making quality

The methodology to be utilized:

- conventional
- biotechnology

Team approach: breeders, physiologists, pathologists, cereal technologists, etc.

b) Breeding spring durum wheat for Northern Kazakstan with emphasis on:

- drought tolerance
- increased yield potential
- increased disease resistance (septoria, stem rust)
- high pasta making quality

The methodology to be utilized:

- conventional
- biotechnology

Team approach: breeders, physiologists, pathologists, cereal technologists, etc.

Note: Durum breeding is probably the lowest priority.

c) Breeding winter wheat for Kazakstan with emphasis on:

- increased yield potential
- increased disease resistance (loose smut, leaf rust, yellow rust)
- high bread and cooky making quality

The methodology to be utilized:

- conventional
- biotechnology

Team approach: breeders, physiologists, pathologists, cereal technologists, etc.

d) Genetic resources:

- collections in Southern and Northern Kazakstan
- germplasm exchange
- evaluation
- documentation
- strengthening the gene bank

e) Human resources and infrastructure:

- scientific staff exchange
- training: short term, undergraduate and postgraduate
- capital investment in research equipment

Work Group 2: Agronomy and Crop Production

Each of the following recommendations needs to be evaluated and adapted to specific conditions at different sites within the wheat producing area of Kazakhstan.

- a) Crop diversity – Kazakhstan/USA University/ICARDA
 - complementary crops, rotations, possible nitrogen fixing legumes in rotations to enhance production and profitability
- b) Tillage and seed methods – Kazakhstan/ USA University/ICARDA
 - timing of tillage, moisture conservation, no-till (direct seeding) to conserve soil, water and enhance production and intensify production system
- c) Soil fertility/soil quality – Kazakhstan/USA University/ICARDA
 - organic matter, erosion, soil-tillage interaction, green manure, nitrogen fixing complementary crop, effect of practices on soil quality to address crop removal of nutrients and enhance/stabilize soils
- d) Crop protection – Kazakhstan/USA University/CIMMYT
 - biocontrol, IPM, cultural/chemical control, wheat and pests (insects/diseases)
- e) Grain quality – Kazakhstan
 - genotype x management – impacts of agronomics on grain quality
 - grain quality management – post harvest
 - fertility – grain quality interaction

Work Group 3: Seed Production

Seed production in Kazakhstan is large and complex, and includes registration, testing, inspection and processing. Points that need to be recognized:

- a) Quality seed and system to distribute new genetics is important to Kazakhstan
- b) Very difficult situation; links in the seed production system need to be repaired
- c) The Kazakhstan Government needs to address problems of the seed production industry

Recommendation-action plan:

- a) Do a thorough analysis of the entire seed sector through international assistance
- b) Develop an action plan for short- and long-term items based on the above analysis
- c) Develop an action plan for Kazakhstan Government staff and the international community to be used to solicit support

Work Group 4: Input Supply, Marketing, Prices and Returns

Broad domestic policy issues were discussed resulting in the following topics as examples of possible projects in this area:

- a) Case study of the wheat production sector
- b) Comparative efficiency of various types of farm units
- c) Comprehensive study of the marketing sector

Appendix 2

Potential Projects for International Collaboration Suggested by Kazak Agricultural Research Institutions

1. Technology for sustainable bread and durum wheat production with 16-19% grain protein content and high technological grain quality index.
2. Sustainable production of high quality spring wheat in Northern Kazakhstan.
3. Establishment of a CIMMYT outreach office at the A.I. Barayev Kazak Institute of Cereal Production aimed at studying world collections of wheat genetic resources.
4. Utilization of wheat wild relatives in breeding resistant bread wheat varieties.
5. Development of high quality spring wheat seed production technologies in Northern Kazakhstan.
6. Breeding early maturing spring wheat varieties using hybridization and advanced biotechnology methods. A.I. Barayev Institute of Cereal Production. 1998-2002.
7. Breeding early maturing spring bread wheat varieties resistant to drought, immune to brown rust, stem rust and septoria spot blotch with 16-19% grain protein content. A.I. Barayev Institute of Cereal Production. 1988-2002.
8. Development of durum wheat varieties with high yield potential, superior grain quality, and disease and stress resistance.
9. Multilocational testing of new Kazak varieties in different environments to identify high quality spring and winter wheat.
10. Development of soil fertility optimum models for different levels of yield and crop rotation. Akmola Agricultural University. 1998-2003.
11. Proposals on establishing crop cultivation and processing machinery service and technology stations based on JSC "Kazagroremmash" enterprise and National Academic Center of Agricultural Research state experiment farms.
12. Milling and baking quality assessment of new varieties and advanced lines of spring bread and durum wheat.
13. Multiplication of early maturing, drought resistant spring bread wheat varieties in the Northern regions of Kazakhstan by the A.I. Barayev Kazak Institute of Cereal Production. 1998-2001.
14. Evaluation of mega-environments for growing of spring wheat in Kazakhstan on the basis of yield and grain quality. State Committee of Variety Testing.
15. Monitoring the population structure of leaf rust (*Puccinia recondita*), septoria spot blotch (*Septoria nodorum*) and the role of wheat variety distribution in disease epidemics. Kazak Crop Protection Institute. 1998-2000.
16. Development of spring wheat protection systems against the major pests based on resistant varieties. Kazak Crop Protection Institute. 1998-2000.
17. Optimization of maturity dates, improvement of yield and grain and seed quality of spring wheat in the dark-chestnut soils of Northern Kazakhstan. Akmola Agricultural University. 1998-2003.

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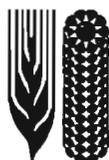
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