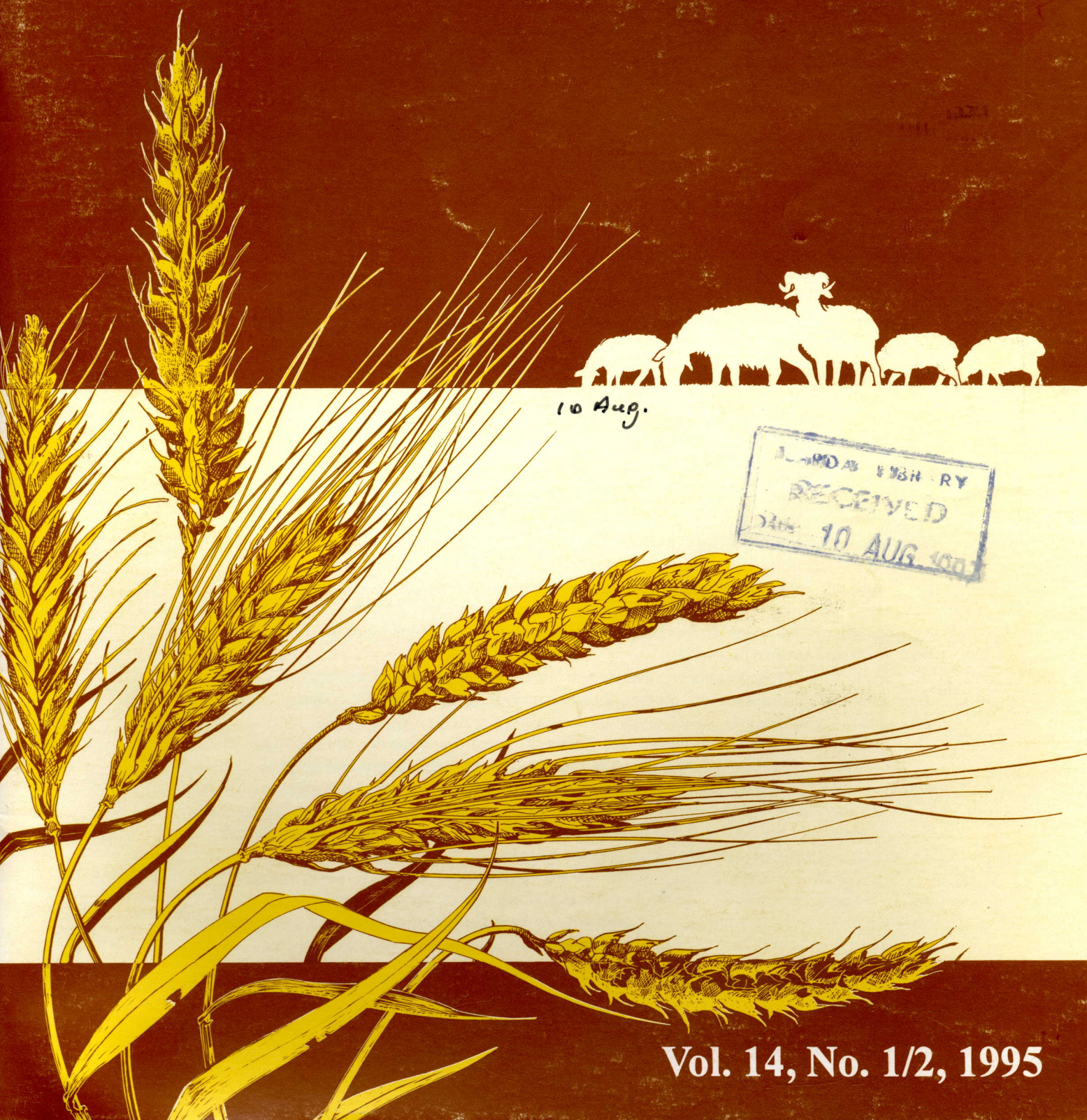
RACHIS

Barley and Wheat Newsletter



Vol. 14, No. 1/2, 1995

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Book: Evans, L.T. and W.J. Peacock (ed.). 1981. Wheat Science – Today and Tomorrow. Cambridge University Press, Cambridge, UK.

Thesis: Haitham Sayed, Mahmoud. 1990. Ecological study of important wild genetic resources of wheat and barley. Thesis. University of Aleppo, Syria.

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Barley and Wheat Newsletter

Rachis, the barley and wheat newsletter, is published half-yearly by the International Center for Agricultural Research in the Dry Areas (ICARDA). It contains mainly short scientific articles, but also includes book reviews and news about training, conferences and scientists in barley and wheat.

The subscription price is US$ 20.00 per year (two issues). However, cereal researchers and the libraries of institutions conducting research on barley and wheat in West Asia and North Africa may apply for a free subscription. In either case, please contact: Rachis/ CODIS, ICARDA, P.O. Box 5466, Aleppo, Syria. Contributions to *Rachis* should be addressed to the Rachis Editor, CODIS.

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Foreword

Barley is the world's fourth most important grain crop both in area and production. Because of its resistance to drought and other stresses, its relative importance in the marginal and low-input areas of the developing world is even greater.

There is a growing demand for barley in the developing world that can only be met through an increase of yield per unit area by modern cultivation practices. Cultivation practices used by farmers in the developing world are changing rapidly, like the introduction of fertilizer and the change from fallow–cereal rotation to continuous cereals. As a result, the threat posed by plant-pathogenic fungi is increasing. Protecting the crop by chemical means is undesirable and mostly not economical. In order to develop plant-protection methods that are sustainable and affordable to farmers in the Third World, studies on the epidemiology of barley diseases and on resistance mechanisms are necessary.

ICARDA has, within the CGIAR system, the global responsibility for barley improvement. Improvement of a crop is not just breeding for higher yield potential, but also for improving quality and disease resistance. Pathology has therefore always received special attention within ICARDA's barley project.

Genetic crop improvement for disease resistance or other traits is only possible if genetic diversity is present. ICARDA is working in the region where barley was domesticated and where great genetic diversity for barley is still present in farmers' fields. The study of plant diseases in the center of origin, and the identification of disease resistance is worthy of international effort. ICARDA is committed to assisting national programs in breeding and pathology. As part of this effort, ICARDA organized this International Workshop on Barley Leaf Blights, in collaboration with Montana State University, at ICARDA's headquarters near Aleppo, Syria in March 1993. This workshop, sponsored by USAID, brought together nearly 50 barley pathologists from around the world. Through events like this, scientists from different countries can establish contacts that will be of mutual benefit and ultimately to the benefit of all barley producers.

Adel El-Beltagy
Director General
ICARDA

Preface

Leaf blight diseases (scald, net blotch and spot blotch) are among the most important barley diseases worldwide. The different leaf-blight pathogens share common features in their epidemiologies, but had never previously been addressed as a group in a scientific meeting.

The importance of these diseases is likely to increase in modern farming systems, especially if barley is cultivated continuously without a break crop. The trend to continuous cereal cultivation is especially strong in developing countries. Research on barley leaf blights has therefore received special attention in the collaborative programs between ICARDA and plant pathologists in the West Asia and North Africa region. Disease surveys and resistance-testing programs have been carried out in various countries. In this workshop we tried to present as much as possible of all the recent work in North Africa, West Asia, East Africa and South America.

Next to presentations of work done in those countries where ICARDA is operating, presentations are also made by colleagues from Europe and North America. Agricultural scientists working in the developing world have as their main target increased production of food and feed crops. The main challenge for their colleagues working in industrialized countries is now to change their agricultural systems from highly wasteful on energy and sometimes environmentally polluting to systems that can be sustained in the long term.

Although the kind of problems facing plant pathologists may seem rather different, solutions to these problems might be common. Crop protection methods based on fungicides are undesirable, either because of the danger to the environment or because the costs are too high for low-output stressful environments.

Resistance breeding provides a cheap and sustainable method of controling plant diseases. However, a better understanding of the epidemiology of pathogens in different growing environments is necessary if we are to develop strategies to use resistance genes in a more durable way. International cooperation among plant pathologists in research is essential, not least as the movement of plant pathogens is not restricted by country boundaries.

This workshop was organized as part of a special project on 'Barley Diseases and Related Breeding Strategies.' The project is executed in collaboration with Montana State University (MSU) and funded by USAID. ICARDA is grateful to both MSU and the donor for the excellent collaboration over the years.

Reaction of Turkish and German Barley Varieties and Lines to the Virulent Strain T_4 of *Pyrenophora teres*

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Abstract

Net blotch causes important crop losses to barley (*Hordeum vulgare* L. subsp. *vulgare*) in Turkey nearly every year. Although several measures can be taken against the disease, the most important is to develop resistant varieties and lines. For this, it is essential to determine the resistance genes involved. The reaction of 82 Turkish and German barley varieties and lines was tested against one of the most virulent Turkish strains, T_4, of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.). Three lines were resistant to the disease and a further 7 moderately resistant.

Key words: *Hordeum vulgare*; barley; selection; varieties; disease resistance; *Pyrenophora teres*; Turkey.

Introduction

In Turkey, barley is a major crop and is used for beer and feed. Barley is cultivated on some 3.4 million hectares and production is 4.5 million tonnes (Anonymous 1989). After wheat (*Triticum* spp.), barley is in the most important crop in Turkey. Many diseases affect barley yield and quality, of which net blotch is the most important (Aktaş 1983).

Although several chemical control measures for net blotch are reported from various countries (Jordan and Best 1981; Martin 1985; Sheriden and Grbavac 1984), none are used in Turkey. In 1984, the disease was found in 70% of production fields in the Central Anatolian Region with an average disease intensity of 13.4% (Aktaş 1987). The major reasons for the wide distribution and high intensity are that seed treatments are not used and susceptible varieties are grown. Although several measures can be taken against the disease, the most appropriate is to develop resistant varieties.

In this study, Turkish and German barley varieties and lines were tested to select parents for the crossing program.

تأثر الأصناف والسلالات التركية والألمانية إزاء السلالة الممرضة *Pyrenophora teres* `d T4

الملخص

يسبب التبقع الشبكي خسائر هامة في محصول الشعير (*Hordeum vulgare* L. subsp. *vulgare*) في تركيا كل سنة تقريبا. ورغم إمكانية اتخاذ إجراءات عديدة للقضاء على هذا المرض، فإن أكثرها أهمية يتجلى في استنباط أصناف وسلالات مقاومة. ولهذا السبب، فإن من المهم تحديد مورثات المقاومة ذات العلاقة. وقد تم اختبار تأثر 82 صنفا وسلالة تركية وألمانية إزاء أكثر السلالات التركية فوعية وهي T4 من *Pyrenophora teres* (Sacc.) Shoem. (= *Drechslera teres* Drechs.)، فكانت ثلاث سلالات مقاومة للمرض وسبع أخرى متوسطة المقاومة.

Material and Methods

Studies were carried out in greenhouses and climate rooms at the Agricultural Faculty, Munich Technical University, Weihenstephan, and at the Plant Protection Research Institute, Ankara. Eighty-two barley lines were tested against the highly virulent Turkish strain of *P. teres*, T_4 (Aktaş 1987). A randomized block design with three replicates was used with pots of 10 plants as the experimental unit. Inoculations were made at the three-leaf stage (Keeling and Banttari 1975). Inoculum was obtained from 14-day-old *P. teres* cultures grown in a nutrient medium containing vegetable agar (200 ml 0.025% Libbys Gemüsechaft + 16 g Bacto-agar + 0.025% $CaCO_3$ + 800 ml water) at 20–22°C in a 12-h light regime. The inoculum concentration was 1.1×10^3 conidia/ml. Plants were kept at 95% relative humidity for 72 h (Sing 1963; Khan 1972; Aktaş 1983, 1987). One drop of Tween-20 was added for every 100 ml inoculum suspension (Chakrabarti 1968; Keeling and Banttari 1975; Aktaş 1983, 1987).

The studies in Germany started on 2 June 1986 and inoculations were made on 23 June. Twelve days later (5 July), plants were evaluated (Fig. 1, 2 and 3). In the studies carried out in Turkey, inoculation and evaluation were carried out on 15 and 25 February 1993, respectively.

Evaluations for barley net blotch were made 10–12 days after inoculation (Tekauz 1985; Aktaş 1987) and the highest disease intensity in every replicate was used to determine the resistance level.

Figure 1. Barley lines inoculated with *Pyrenophora teres*.

Figure 2. Barley leaves 10 days after inoculation with *Pyrenophora teres*.

Fig. 3. Resistant Dura barley variety inoculated with *Pyrenophora teres*.

Results and Discussion

Of the 82 barley lines tested, only 3 (Andrea, Dura and Sigra) were resistant (R) to strain T_4 of *P. teres* (Table 1, Fig. 4 and 5). Resistance in barley to *P. teres* is controlled by three genes: Pt_1, Pt_2 and Pt_3. They are dominant, but only partially; complete resistance can be achieved by bringing these three genes together (Khan and Boyd 1969). Chakrabarti (1968) studied 6246 barley varieties from the world collection, and found 417 of them resistant to the pathogen, of which 30 were highly resistant. Khan (1972) studied 8756 Turkish lines and found 6 highly resistant. In our study, as well as the 3 resistant lines, another 7 (Arena, Doris, Europa, Ginso, Hydra, Katja and Viola) were moderately resistant (MR). The rest were moderately susceptible or susceptible (MS–S).

All 22 Turkish barley lines were susceptible to *P. teres*. These results show that the resistance has been neglected in breeding programs, even though net blotch causes yield losses in Turkey. Breeding programs need to pay more attention to this pathogen in the future.

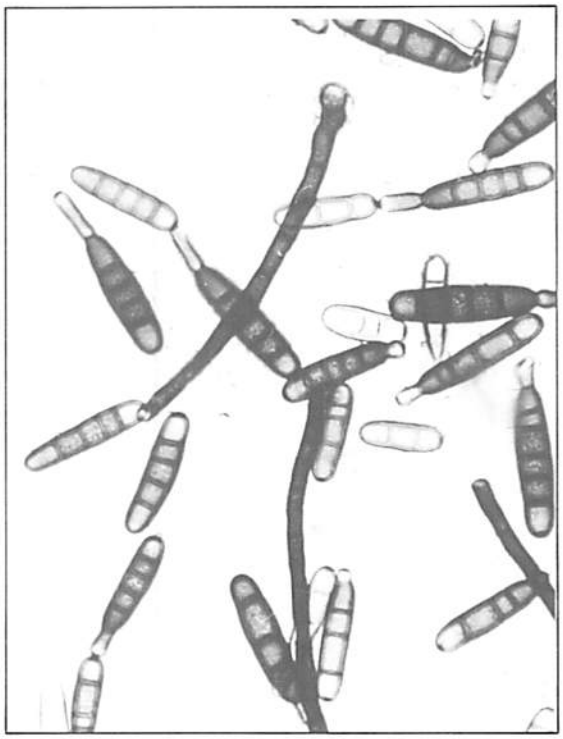

Fig. 4. Conidia and conidiophores of *Pyrenophora teres*.

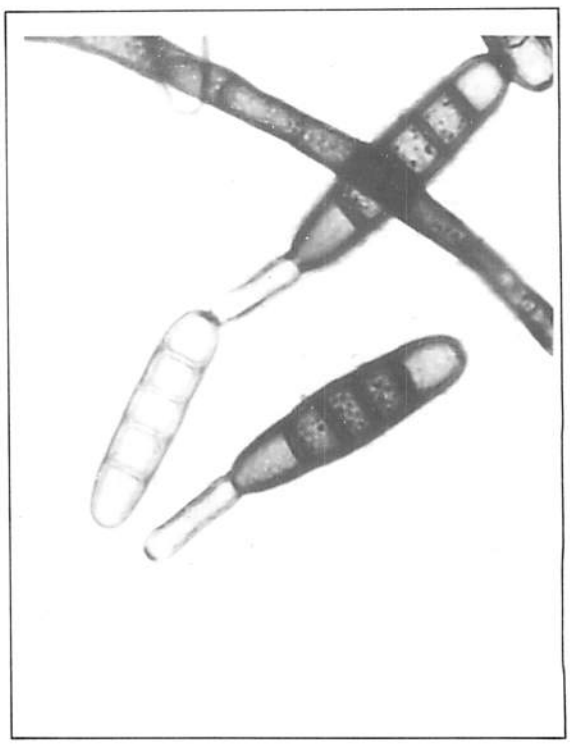

Fig. 5. Conidia of *Pyrenophora teres*.

Table 1. Reaction of Turkish and German barley genotypes against virulent T_4 strain of *Pyrenophora teres*.

Var./line†	Reaction	Var./line	Reaction	Var./line	Reaction
Adonia (G)	S	Efes-2 (T)	S	Kocaoğlu-85 (T)	S
Alraune (G)	S	Efes-3 (T)	S	Koral (G)	S
Anadolu-86 (T)	S	Erginel-90 (T)	S	Largo (G)	S
Andrea (G)	R	Ermo (G)	S	Luna (G)	S
Ankara-86 (T)	S	Esther (G)	S	Mammut (G)	MS
Apex (G)	S	Europa (G)	MR	Multum (G)	S
Aramur (G)	S	Franka (G)	S	Obruk 86 (T)	S
Arena (G)	MR	Gebel (G)	MS	Optima (G)	S
Asse (G)	S	Ginso (G)	MR	Petra (G)	S
Aura (G)	S	Glaudia (G)	S	Sanja (G)	S
Barolina (G)	S	Gloria (G)	S	Severa (G)	MS
Beate (G)	S	Golf (G)	MS	Sigra (G)	R
Bollo (G)	MS	Guantum-85 (T)	MS	Sonate (G)	S
Bülbül-90 (T)	S	Gunhild (G)	S	Stering (G)	S
Camolat (G)	S	Gytris (G)	S	Tapir (G)	MS
Candica (G)	S	Hamidiye-85 (T)	S	Tilli (G)	S
Carolina (G)	S	Harry (G)	S	Tokak 157/37 (T)	S
Catinka (G)	S	Helena (G)	S	Trumpt (G)	MS
Cerise (G)	S	Hydra (G)	MR	Ultra (G)	S
Cordula (G)	S	İgri (G)	S	Viola (G)	MR
Corona (G)	S	İrania (G)	S	Welam (G)	S
Cumhuriyet-50 (T)	S	Irla (G)	S	Yerçil 147	MS
Danilo (G)	S	Kaskade (G)	S	Yeşilköy 387 (T)	S
Detto (G)	S	Katja (G)	MR	Yıldırım (T)	S
Dorett (G)	S	Kavak 7531 (T)	S	Zafer 160 (T)	S
Doris (G)	MR	Kaya (T)	S	69147 (T)	S
Dura (G)	R	Kılıç (T)	S	4772 (T)	S
Efes-1 (T)	S				

† T = Turkish varieties/lines; G = introduced German germplasm.

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Investigations on the Etiology, Biology, Epidemiology and Control of the Causal Agents of Barley Leaf Blights in France

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Abstract

In France, investigations on barley (*Hordeum vulgare* L. subsp. *vulgare*) blights have mostly concerned (i) the biology, symptomatology, epidemiology and control of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.), which has become a major barley pathogen in relation to the systematic use of chemical treatments (iatrogenic parasitism), (ii) the epidemiology of the mosaic complex (barley yellow mosaic virus and barley mild mosaic virus) which gradually spread over most of the barley cropping areas, and, to a lesser extent, (iii) the pathology of *Rhynchosporium secalis* (Oud.) J.J.Davis and *Pseudomonas syringae* van Hall in relation to the rapid development of satisfactory chemical treatments against *R. secalis* and to the continued underestimation of *P. syringae* or its confusion with *P. teres* f.sp. *maculata* Smedegaard-Petersen.

The various possibilities for controlling the two formae speciales (*teres* and *maculata*) of *P. teres* are being investigated by the Laboratoire d'Ingénierie Agronomique, Ecole Nationale Supérieure Agronomique de Toulouse. They include: (i) the genetic improvement of barley resistance through hybridization, mutations, *Hordeum bulbosum* L. technique and embryo culture; (ii) the assessment of the effects of the chemical environment

دراسات على أسباب وحيوية ووبائية ومكافحة العوامل المسببة لأمراض لفحة الأوراق على الشعير في فرنسا

الملخص

في فرنسا، تُولي الدراسات على أمراض لفحة الأوراق التي تصيب الشعير (*Hordeum vulgare* L. subsp. *vulgare*) ، أهمية كبيرة لـ (1) بيولوجية وأعراض ووبائية ومكافحة *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.) الذي أصبح عاملا ممرضا رئيسيا على الشعير فيما يتعلق بالاستخدام المنتظم للمعاملات الكيميائية (التطفل الطبي المنشأ)، (2) وبائية مركب التبرقش (فيروس اصفرار وتبرقش الشعير وفيروس تبرقش الشعير المعتدل) الذي ينتشر تدريجياً في معظم مناطق زراعة الشعير، وإلى مدى أقل (3) للأسباب الممرضة لـ *Rhynchosporium secalis* (Oud.) J.J. Davis و *Pseudomonas syringae* Van Hall من حيث التطور السريع للمعاملات الكيميائية المُرضية ضد *R. secalis* والاستمرار في الاستخفاف بـ *P. syringae* أو تداخله خطأً مع *P. teres* f.sp. *maculata*. ويقوم مختبر الهندسة الزراعية في المدرسة الزراعية الوطنية العليا في تولوز بدراسة الإمكانات المتعددة لمكافحة الشكلين الخاصين (*teres* و *maculata*) من *P. teres* وتشمل تلك الإمكانات : (1) التحسين الوراثي لمقاومة الشعير من خلال التهجين، الطفرات، تقنية *Hordeum bulbosum* L. وزراعة الأجنة، (2) تقييم تأثيرات المواد الكيميائية (مبيدات الفطور والأعشاب والحشرات) على تطور العامل الممرض و(3) التغييرات المحتملة في أساليب إدارة المحصول، مع إدخال المكافحة الحيوية (أي استخدام الأعداء الفطرية والبكتيرية كمبيدات آفات حيوية) للحد من المستويات الوبائية.

(fungicides, herbicides and insecticides) on pathogen development; and (iii) possible changes in crop management techniques, with the introduction of biological control (i.e. the application of fungal and bacterial antagonists as biopesticides), to limit epidemic levels.

Key words: *Hordeum vulgare*; barley; disease resistance; breeding methods; chemical control; biological control; crop management; *Pyrenophora teres*; *Rhynchosporium secalis*; *Pseudomonas syringae*; aetiology; epidemiology; biology; France.

Introduction

During the last 40 years, the barley area in France has fluctuated widely. From 1 million ha in 1950, it rose to 3 million ha in 1970 following the introduction of spring barley cultivars of Scandinavian origin (e.g. Rika in 1951), with 2.6 million ha of spring barley compared with only 0.3 million ha of winter barley. In the 1970s, the area of spring barley decreased markedly whereas the winter barley area increased steadily: in 1978, winter barley covered 1.4 million ha while spring barley covered only 0.7 million ha. In 1990, the area devoted to winter barley had been maintained at 1.4 million ha, whereas the area of spring barley had declined further (0.4 million ha). Overall, French production amounted to 10 million tonnes of barley; France was thus the third largest producer, behind the former USSR and the USA (according to ITCF, France).

Barley Pathology in France

Six diseases are presently responsible for most of the barley yield losses in France; four fungal and two viral diseases:

- scald caused by *Rhynchosporium secalis* (Oud.) J.J.Davis, especially early in wet springs when the temperature is relatively low;
- powdery mildew caused by *Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal (= *Oidium monilioides* Desm.), which is dangerous during the seedling and tillering stages;
- brown rust caused by *Puccinia hordei* Otth, which is nearly always present, with outbreaks occuring during the stem-extension stage in mild and rainy weather;
- leaf blotch (net blotch, spot blotch) caused by *Pyrenophora teres* Drechs. (anamorph: *Drechslera teres* (Sacc.) Shoem.), with severe attacks after heading stage in all barley cropping areas which, in the absence of efficient chemical treatments (Maufras and Reiner 1990), result in yield losses of 15–25% (Barrault 1989; Albertini, Barrault and Caron, personal observations between 1960 and 1992);
- barley yellow dwarf virus (BYDV), a luteovirus transmitted by various aphids not only to barley, but also to wheat (*Triticum* spp.) and oats (*Avena sativa* L.) in all areas (Vacher 1989); and,
- the mosaic complex – yellow mosaic (BYMV) and mild mosaic (BMMV) – caused by closely related potyviruses (Hariri et al. 1990) and transmitted by the myxomycete *Polymyxa graminis* Led.; reported for the first time near Rheims in 1974, the mosaic viruses are now all over France, except in the west (Lapierre et al. 1991).

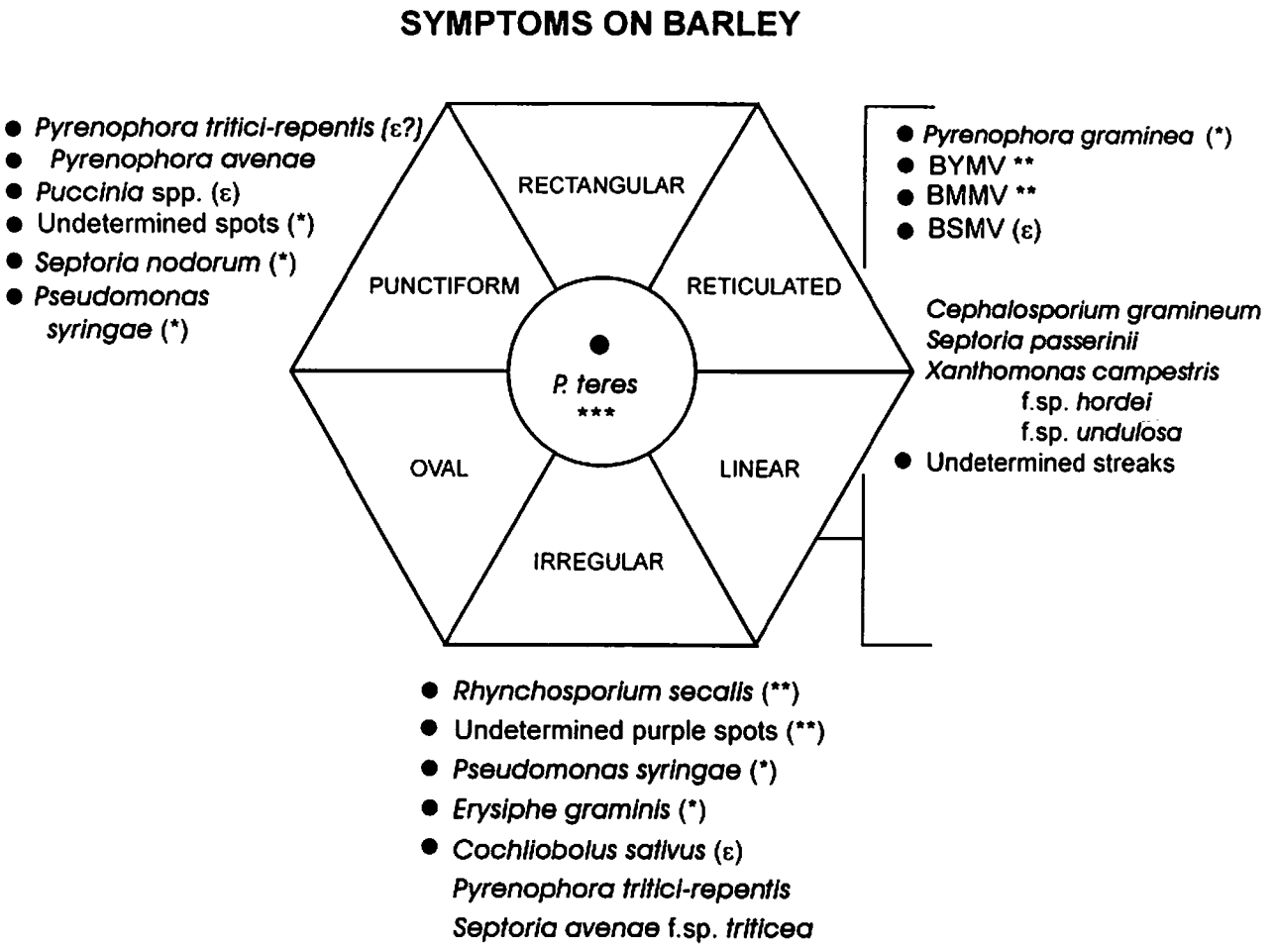
Barley in France is attacked to a lesser extent by other pathogens, but serious damage is localized to favorable climatic and/or soil conditions. These pathogens are:

- *Pyrenophora graminea* S.Ito & Kuribay. (anamorph: *Drechslera graminea* (Rab.) Shoem.), the causal agent of barley stripe, and *Ustilago nuda* (Jens.) Rostr., the causal agent of barley true loose smut, when the seed treatment is ineffective (e.g. after the acquired tolerance of the pathogen to a systemic fungicide);
- *Leptosphaeria nodorum* Müller (anamorph: *Septoria nodorum* Berk.), the causal agent of brown spot symptoms on blades and stalks, and of glume blotch, with usually little effect on yield (Barrault 1989; Caron, personal observation, 1992);
- *Cochliobolus sativus* (Ito & Kurib.) Dreschs. ex Dast. (anamorph: *Bipolaris sorokiniana* (Sacc.) Shoem.), particularly on barley volunteers – a susceptibility scale of the cultivars grown in France has been established; and,
- *Pseudomonas syringae* van Hall, reported on barley in France for the first time by Barrault in 1977, with leaf-blight symptoms between tillering and heading. A number of major winter barley cultivars grown in France are susceptible to this pathogen which can cause significant damage (Barrault 1989).

Barley Leaf Blight Symptoms and Causal Agents

Figure 1 shows the six forms of blight symptoms observed on barley leaves attacked by *Pyrenophora teres*. The reticulated phase is caused by f.sp. *teres*, whereas the other five phases are due to f.sp. *maculata* (Burdugo 1968; Barrault 1982, 1989). Figure 2 shows the distribution of barley leaf blight symptoms in France in 1988 and 1991.

Taking into account the crop management conditions, particularly the chemical treatments, the main causal agents of barley leaf blight symptoms observed on barley leaves in France (Fig. 1), in decreasing order of economic importance, are: *Py. teres*, BYMV–BMMV, *R. secalis*, *Ps. syringae*, *E. graminis* and *L. nodorum*. The irregular purple spots of undetermined origin which appear after heading on (e.g.) cultivars Arma and Barberousse (Barrault 1989) and which constitute a serious and unsolved problem, can be placed in the list at the level of *R. secalis*. The symptoms may be due to climatic or other factors (Barrault and Albertini 1993), including adverse reaction to the use of chemical treatments (Clark et al. 1979) causing host physiology modifications. Various



● Occurrence in France
*** very frequent and often severe
** frequent locally and often severe
* relatively frequent locally and low severity
ε occurrence without severity

BYMV: Barley yellow mosaic virus
BMMV: Barley mild mosaic virus
BSMV: Barley stripe mosaic virus

Figure 1. ***Pyrenophora teres*** **induces six forms of leaf spot in barley: the reticulated facies are due to *P. teres* f.sp. *teres*, whereas the other five symptoms are caused by *P. teres* f.sp. *maculata*. Various other identified pathogens and undetermined stimuli cause the appearance of symptoms similar to some of those induced by *P. teres* f.sp. *maculata*.**

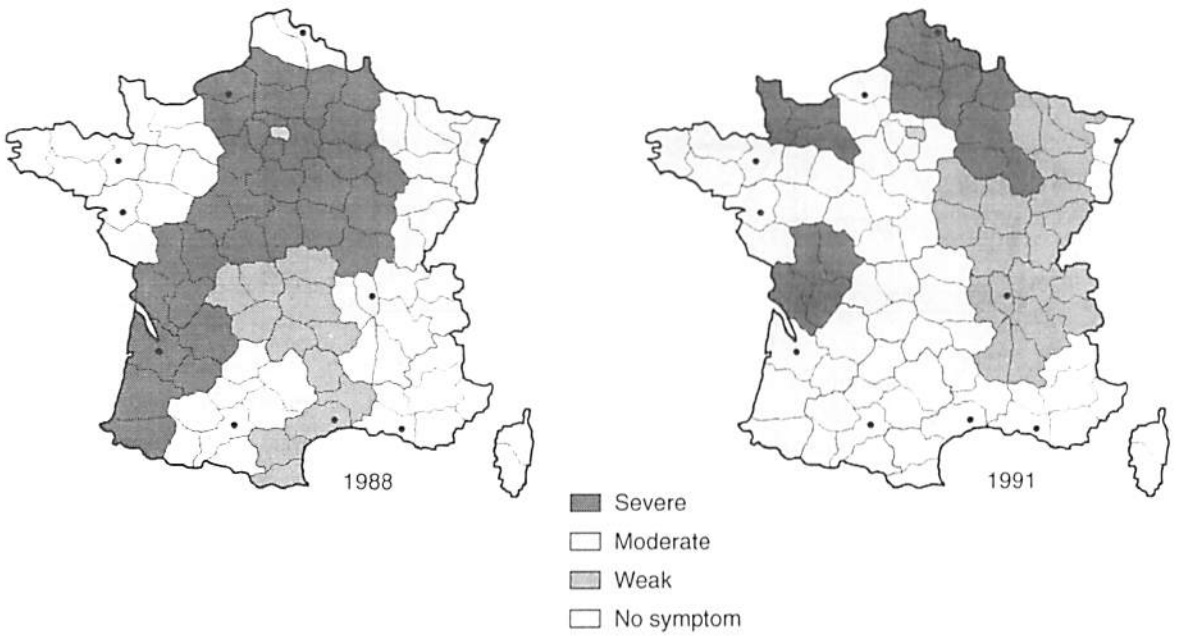


Figure 2. Occurrence and severity of leaf blights (*P. teres* and others) in France, 1988 and 1991. (SPV, Bordeaux.)

(punctiform, linear) amphigenic asymmetrical necrotic spots without perinecrotic chlorosis can be added to the end of the list. They are also of undetermined origin and appear at heading on several cultivars (Robur, Alpha, Plaisant) not only on the leaves, but also on the stems and ears (Barrault and Albertini 1993).

In France over the last two decades, research on barley leaf blights has concentrated on the biology, symptomatology, epidemiology and control of *Py. teres* (which became the major barley pathogen as a result of systematic chemical treatment of the crop), of the BYMV and BMMV mosaic complex (which has gradually extended to most barley cropping areas; Fig. 3) and, to a lesser extent, of *R. secalis* and *Ps. syringae*. The development of satisfactory chemical treatments against *R. secalis* was achieved relatively rapidly (Jordan and Tarr 1982). Breeders and scientists had underestimated the occurrence of *Ps. syringae* for a long time or had confused it with *Py. teres* f.sp. *maculata* (Barrault 1989).

Investigations on *Pyrenophora teres* in France

The pathology team of the Laboratoire d'Ingénierie Agronomique of the Ecole Nationale Supérieure Agronomique in Toulouse has been investigating barley leaf blights since the 1960s and, since about 1978, has placed considerable effort on

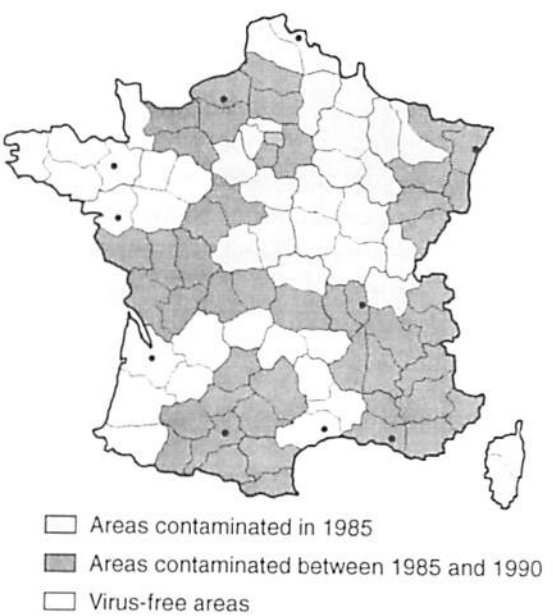


Fig. 3. Spread of Barley Yellow Mosaic Virus and Barley Mild Mosaic Virus diseases in France, 1985–90. (INRA, Versailles.)

detailed investigations on *Pyrenophora teres*. Various inputs, particularly pesticides, modify the soil and atmosphere microflora and cause, through the disappearance of some pests and antagonistic saprophytic microflora, the emergence of pathogens which are the causal agents of iatrogenic diseases. Detailed analyses of the *P. teres*–barley system are given by Berdugo (1968) and Barrault (1989).

Various approaches have been explored for the control of this pathogen. These include genetic improvement of barley resistance through hybridization and mutation (Arabi 1991), chemical control (Bendahmane 1992), the effects of the chemical environment (fungicides used against the other pathogens, herbicides and insecticides generally applied to barley) on the development of *P. teres* (Toubia-Rahme 1992), and biological control through bacterial and fungal antagonists (Mostafa 1982; Mostafa et al. 1983; Ali-Haimoud et al. 1993).

For the genetic improvement of resistance to both forms of *P. teres*, a rapid and simple laboratory method using leaf disks was developed to assess the genetic resistance of cultivars. This method gave results highly correlated with resistance determined on seedlings in the laboratory or on whole plants in the field (Arabi 1991; Arabi et al. 1991c). Results from the three methods showed that host resistance to the pathogen strains used was partial, dominant and horizontal. Analysis of reciprocal crosses among nine barley genotypes, including tolerant cultivars from the Middle East (such as Arrivate and 79-S10-10), showed high general (GCA) and specific (SCA) combining abilities with no maternal effects for yield and 1000-seed weight of healthy or diseased plants (Arabi 1991; Arabi et al. 1990). In parallel, barley dihaploids were obtained from F_1 hybrids (*P. teres*-resistant parent × susceptible, but agronomically valuable, parent) pollinated by *Hordeum bulbosum* and embryo cultured (Arabi 1991; Arabi et al. 1991b). The dihaploid yield, defined by the ratio of fertile doubled haploids to the *H. bulbosum* pollinated flowers, varied from 3 to 9% depending on in relation to the quality of the *H. vulgare* genotype (in particular, two- or six-row), on the *H. bulbosum* clone and on the climatic conditions (Arabi 1991; Arabi et al. 1991b). Stable barley types were readily obtained and the quantitative transfer of resistance genes (from the tolerant parent) was accompanied, in some dihaploids, with the beneficial quantitative transfer of some agronomic traits of the susceptible parent, such as yield, number of seeds/ear, 1000-seed weight, shorter straw and earliness (Arabi 1991; Arabi et al. 1992).

Low (<160 Gy) ^{60}Co-irradiation of the seeds of five cultivars was used to develop mutants that were both resistant to *P. teres f.sp. maculata* and agronomically desirable. The number of non-chlorophyll mutants in M_2 varied with cultivar and dose applied (Arabi 1991; Arabi et al. 1991a). Studies on the dihaploids and selected mutants are continuing.

For chemical control of the pathogen, the effects of 76 commercial active ingredients and two code-numbered triazoles on *P. teres* were investigated (Bendahmane 1992). *In vitro* some contact fungitoxic chemicals (anizaline, chlorothalonil) and some systemic fungicides (imidazoles: imazalil, prochloraz; triazoles: diniconazole, flusilazole, propiconazole) strongly inhibited conidial germination and mycelial growth of the two pathogen forms. In most cases susceptibility was lower for the *maculata* form. The difference in behavior between the two pathogen forms was larger in the case of conidiogenesis: prochloraz and diniconazole at 10^{-7} M/L totally inhibited the process in f.sp. *teres*, whereas it was only decreased by 26 and 7%, respectively, in *maculata* (Bendahmane et al. 1992). *In vivo*, only chlorothalonil stopped further spread of the disease and some systemic fungicides (mentioned above and active *in vitro* on the mycelium) prevented disease development or cured the plants (from 24 h prior to artificial contamination to 72 h after contamination) in a growth chamber; f.sp. *maculata* was insufficiently inhibited in the curative treatments. In the field, the preventive effect of the chemicals corroborated that observed in the growth chamber, and cure only occurred in *teres*-infected plants (Bendahmane 1992). The problem of chemical control of the pathogen, particularly *maculata*, in the standing crop remains unsolved. Even the best chemicals, flusilazole and cyproconazole, decreased attacks in France by only 45 and 42%, respectively (Maufras and Reiner 1990). In 1991, tebuconazole, flusilazole and propiconazole, resulted in decreased attacks of only 47, 43 and 41%, respectively (Caron, ITCF, personal observation).

The investigation of the effect of the chemical environment on the development and pathogenesis of *P. teres* on barley showed that, *in vitro*, fungicides such as benomyl, carbendazim, sulfur and triadimefon, stimulated some parts of the pathogen cycle (Toubia-Rahme et al. 1992). Under controlled conditions, benomyl, carbendazim and neburon stimulated the development of the disease (sporulation included) by either pathogen form using both preventive and curative application. Under the same conditions, triadimefon, deltamethrin and MCPP stimulated the pathogenesis and sporulation of only one pathogen form (*teres* for the first two pesticides and *maculata* for the third) (Toubia-Rahme 1992). Sulfur and 2,4-D promoted only the sporulation of the pathogen *in vivo* (Toubia-Rahme 1992). In the field, carbendazim significantly decreased the latent period of *P. teres*, thus enhancing pathogen attack. These data support the iatrogenic character of *P. teres* parasitism. This is in agreement with the observations of Jordan and Best (1981) who noticed increased *P. teres* in the United Kingdom following benzimidazole applications on barley for the curative treatment of *Pseudocercosporella herpotrichoides* (Fron) Deighton.

The Laboratoire d'Ingénierie Agronomique, ENSA, Toulouse, is investigating the behavior of the two pathogen forms on forming and germinating seeds, and also on crop residues and wild *Hordeum* species (particularly *H. murinum* L.). The testa, albumen and embryo of the seeds can be colonized by both forms at flowering. At germination, *teres* appears to be the only form able to infect the first leaf of seedlings systematically (Youcef-Benkada et al. 1993). For the early detection and separation of the two pathogen forms, a serological indexing test is being developed. Preparation of immunosera to characterize specific antigens produced by different strains of the two forms of *P. teres* for their *in-vitro* and *in-situ* identification involve ELISA-like techniques, with immunofluorescence and histo-autoradiography after application of labelled tracers. In parallel, isoenzymatic, RFLP and RAPD analyses will be developed to differente strains. The behavior of the host to different strains will be analyzed using histological and biochemical criteria (PR proteins, anti-enzyme proteins, associated mRNAs).

Early differential diagnosis will be used in barley plots and on neighboring crops to investigate changes in the distribution of the two pathogen forms. Wild barley species might act as inoculum reservoirs for one or both forms. The epidemiological–ecological studies on the two forms of *P. teres* might change the control strategy. Early detection of primary contaminations will allow a better use of chemical treatments. Soil application of biopesticides and adequate crop management could decrease primary attacks.

Investigations on *Pseudomonas syringae*

Since 1978, amphigenic, asymmetrical, oval to irregular, small (3 × 1.5 mm) leaf spots have been observed on barley in all barley cropping areas (Barrault et al. 1986). First translucent, chlorotic, and water-soaked, the spots turn to brown necroses, without perinecrotic chlorosis, with a more or less rapid drying out of the blade. These spots are different from the symmetrical amphigenic spots of *P. teres*, but look like the oval or irregular spots of the *maculata* form.

Two strains were isolated from foliar necroses of highly susceptible barley cultivars (Arma and Alpha) and their pathogenicity was established. The use of staining techniques and biochemical tests led to the identification of *Pseudomonas syringae* for the first time in France (Barrault et al. 1986). The pathovar, for which genetic and behavioral investigation remains to be done, might be *syringae* (cf. Mathre 1982).

Observations carried out over a number of years showed that many barley cultivars grown in France were highly susceptible, including Arma, Alpha, Motan, Jaidor, Robur, Ager, Antarès, Thibaut, Barberousse, Courlis and Métro (Barrault 1989). Although the economic importance has not been estimated, the noticeable frequency and the ability of the pathogen to attack other cereals such as wheat and oats, suggest that it already induces significant yield losses.

Another bacterial pathogen of barley, *Xanthomonas campestris* f.sp. *hordei*, the causal agent of bacterial leaf streak, is so far unknown in France. The pathogen is being investigated in the Laboratoire d'Ingénierie Agronomique together with the INRA experiment Station of Toulouse-Auzeville (Laboratoire de Biologie Moléculaire des Relations Plantes-Microorganismes). The investigation of the distribution of the pathogen in Iran, particularly in the driest areas where barley crops are irrigated, is being followed by analysis of the genetics of the pathogen in relation to its pathogenicity (using RFLP and PCR). The epidemiological and agronomic aspects are also taken into account, with the behavioral investigation of the strains on other cereals and grasses (Alizadeh et al. 1993).

Barley Mosaic Viruses: Barley Yellow Mosaic Virus (BYMV) and Barley Mild Mosaic Virus (BMMV)

The two viruses, which are the causal agents of the mosaic diseases of winter barley, were first observed near Rheims in 1974, spread was rapid and most spring barley is now affected. In 1990, Brittany was the only region where the disease was absent (Meyer 1989; Lapierre et al. 1991) (Fig. 3).

The state of the knowledge on these viruses, their vector (*Polymyxa graminis* Led.) and control were reviewed recently (Hariri et al. 1990; Lapierre et al. 1991). The Department of Virology (INRA Versailles) investigated the behavior and distribution (Fig. 4) of $BYMV_2$, a pathotype which appeared recently in France and is now present in 11 *departements*. $BYMV_2$ overcomes the *Ragusa* resistance gene which is widely used in Europe for the improvement of resistance of *Hordeum vulgare*. The high production of cystosori by BMMV- and $BYMV_1$-resistant cultivars favors the spread of less frequent BYMV strains such as $BYMV_2$ (Hariri et al. 1990).

The genetic resistance of barley to BYMV and BMMV is the only possible method of control: the recessive gene *Ragusa*, which is on chromosome 4, confers immunity to $BYMV_1$ and BMMV (Lapierre et al. 1991). Four other genes which confer resistance to BYMV have been identified in Japan. The induced resistances towards all Japanese pathotypes are total or partial. The Japanese cultivar Mokusekko 3 (*Ym1*) is resistant to $BYMV_2$ in France (Lapierre et al. 1991). In the near future, barley cultivars will be protected through the insertion of genetic information (such as the capside gene which disturbs viral replication) into their genome. Biological control of the *Polymyxa* vector might also be considered.

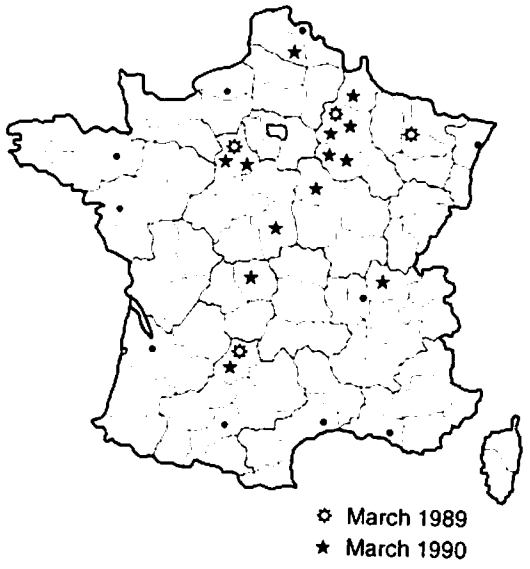


Fig. 4. Occurrence of Barley Yellow Mosaic Virus pathotype 2 in France, 1989 and 1990. (INRA, Versailles.)

Investigations on *Rhynchosporium secalis*, the Causal Agent of Barley Scald

Scald occurs mostly in cold wet areas on barley, rye and various Graminaceae. Although some authors distinguished formae speciales in *R. secalis*, the specificity has not been established (Shipton et al. 1974) as the fungus is polyphagous. In addition to the typical leaf symptoms, two atypical amphigenic and symmetrical symptoms are also observed. These may be confused with spots induced by *Py. teres* f.sp. *maculata*, but the perinecrotic chlorosis caused by *P. teres* f.sp. *maculata* is not observed with *R. secalis*. The first symptom is a brown monochrome necrosis of variable shape, whereas the second necrosis is a light-colored, oval to diamond-shaped spot with a brown margin and a small dark necrosis at the center (Barrault 1989).

In France, scald occurs in all barley cropping areas. Severity is related to spring rainfall and to the soil, tillage, crop rotation and fertilization; few cultivars have satifactory resistance. In winter barley, some older cultivars (Arma, Nymphe and especially Hop) and some more recent varieties (Catania, Energy, Kimono, Matador and Nanouk) are slighthy more tolerant than other varieties.

Little work on the barley–*R. secalis* system has been done in France, but two recent contributions can be mentioned.

The Laboratoire d'Ingénierie Agronomique, in association with the Centre de Physiologie Végétale, Université Toulouse III, showed that low concentrations of a high molecular weight phytotoxic glycoprotein released by cultured *R. secalis* induced chlorotic and necrotic symptoms similar to those observed in the last stages of the disease on barley leaves. These symptoms reflect cell modifications (such as the collapse of epidermal walls, tissue necroses, and xylem-vessel plugging) that are induced by the phytotoxic glycoprotein (Mazars et al. 1989).

Different anti-*R. secalis* sera were obtained from the spores, the mycelium and another toxin (rhynchosporoside) of *R. secalis* (Mille 1990). One of these sera (ssm), which is both sensitive and specific, was valuable for immunofluorescent detection of the pathogen in barley seeds (Mille 1990).

After heading, the coated barley seed can be attacked and colonized by the fungus in the apical zone at the base of the awn. The mycelial stroma under the lemma forms a resting form of the pathogen which can give a primary contamination of the seedling. Analysis of seed lots is therefore important as infected seeds, together with crop residues, ensure the survival and propagation of the pathogen (Mille 1990). Experiments carried out over three years (1984–1986) showed decreased disease incidence after treatment of contaminated seeds with triadimenol (Mille 1987). The seed treatment was as efficient as early treatment of the standing crop at the beginning stem extension (which is more costly).

Chemical control of *R. secalis* in growing barley was introduced in France from 1970 to 1980, under the supervision of the Plant Protection Service. As the cycle of the pathogen and its epidemiology are well documented (see review by Shipton et al. 1974; Stedman 1980; Fitt et al. 1986), a reliable prediction of *R. secalis* attacks is used for the adequate scheduling of chemical treatments. Ergosterol biosynthesis inhibitors (EBI) such as flusilazole, propiconazole and tebuconazole (triazoles), prochloraz (imidazole) and fenpropimorph (a morpholine derivative) can be applied separately or in association with each other or other systemic fungicides (like carbendazim) or with contact fungicides (mancozebe, chlorothalonil). These efficient fungicidal treatments ensure 70–90% control of the pathogen (Index Phytosanitaire, ACTA, 1993). However, the possible appearance of EBI-resistant strains of *R. secalis* cannot be ruled out. In the United Kingdom, some strains of the pathogen displayed high resistance (ratio 200–300) to triadimenol (Kendall and Hollomon 1990). The level of resistance to this fungicide gradually increased from 1981 to 1989 (Jones 1990). Increased tolerance of *R. secalis* strains to propiconazole between 1987 and 1989 was also reported (Jones 1990).

Conclusion

The barley leaf blight complex is characterized by a wide spectrum of symptoms (Fig. 1). As some of the causes remain unknown, etiological investigations have to be carried out to develop control strategies. The improved control of major pathogens such as *P. teres* and the BYMV–BMMV mosaic viruses requires the investigation of all possible ways of genetic (improved host resistance through biotechnology and genetic engineering), chemical (using more efficient and environmentally safe molecules), biological (using antagonists and/or hypovirulent strains) and agronomic (removal of the resting forms of the pathogens or vectors, and enhancement of plant resistance to diseases) control. The research programs should also include *R. secalis*, as the present satisfactory chemical control might be only temporary. The Laboratoire d'Ingénierie Agronomique, ENSA Toulouse, has been involved in such investigations for a long time. In addition to a large number of contributions on *Py. teres*, a major iatrogenic pathogen, the team has also been investigating, through biological and microbial genetic approaches, the causal agents of barley leaf blight and streak (*Ps. syringae* and *X. campestris*).

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Evaluation of Ethiopian Barley Landraces for Disease and Agronomic Characters

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Abstract

Ethiopia is generally considered a center of secondary diversity for barley (*Hordeum vulgare* L. subsp. *vulgare*), because of the presence of great genetic diversity and endemic forms. For this reason, Ethiopian barley germplasm is of considerable importance to barley breeding worldwide. The vast majority of Ethiopian barley is still in the form of landraces, or farmers' varieties,

تقييم الأصول المحلية الإثيوبية من الشعير من حيث الأمراض والصفات الزراعية

الملخص

تعتبر إثيوبيا بشكل عام مركزاً للتنوع الثانوي من الشعير (*Hordeum vulgare* L. subsp. *vulgare*)، وذلك لوجود تنوع وراثي كبير وأشكال متوطنة. ولهذا السبب، تعتبر أصول الشعير الوراثية الإثيوبية على جانب كبير من الأهمية في عملية تربية الشعير على نطاق العالم. ومازال القسم الأكبر من الشعير الإثيوبي على شكل أصول محلية أو أصناف مزارعين، خلائط غير متجانسة (متنافرة) من طرز وراثية تم اختبارها لتخفيف مخاطر فشل المحصول في الأراضي الهامشية حيث يزرع الشعير. ولدراسة التغاير ضمن الأصول المحلية الإثيوبية من حيث مقاومة الأمراض والصفات الزراعية، أخذ 180 مدخلاً من مركز المصادر الوراثية النباتية في إثيوبيا لتمثل المواد التي تم جمعها من المناطق

heterogenous mixtures of genotypes selected to spread the risk of crop failure on the marginal land where the crop is grown. To study the variation within Ethiopian landraces for disease resistance and agronomic characters, 180 accessions from the Plant Genetic Resources Center of Ethiopia were taken to represent material collected in the regions around Holetta, Sheno and Bekoji. The material was assessed on research stations at the same three locations. Disease was encouraged by the use of a susceptible cultivar (Ardu 12-8C) at all sites, and by distributing infected crop debris (at Holetta only). Scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) was prevalent at all three locations, while net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) was important at Bekoji and also present in Holetta. Sixty lines resistant or moderately resistant to both diseases, from each collection site, were selected and placed in agronomic trials. Great variation was evident in days to heading, days to maturity and plant height, showing the possibility for selecting pure lines adapted to each specific environment.

Key words: *Hordeum vulgare*; barley; landraces; evaluation; disease resistance; agronomic characters; *Pyrenophora teres*; *Rhynchosporium secalis*; Ethiopia.

Introduction

Barley is a major cereal crop of Ethiopia, accounting for about 20% of the cereal production in the country. Although barley is the main crop above 2000 m altitude, it is mainly cultivated in stressed and higher-elevation areas (above 2800 m). Conditions in these areas are marginal for other cereals (Berhane 1991). Barley is mainly grown for human food and homemade beverages; the straw is used as animal feed and for bedding. Environmental stresses such as frost, low pH and waterlogging, in addition to low soil fertility and inadequate agronomic practices are the main causes of the low productivity (about 1.0 t/ha) of barley in Ethiopia.

Ethiopia is considered to be a center of secondary diversity for barley, but because of the tremendous range of genetic diversity and endemicity of forms (e.g. *defeciens* and irregular types), it is also considered a possible center for barley's origin by some authors (Harlan 1973). Ethiopian barleys have distinct grain color (purple or black), short-haired rachilla (Qualset 1975; Ward 1962), virus resistance (Malak 1975) and high lysine content (Harlan 1973; Munck 1972; Munck et al. 1970). Other useful characteristics of Ethiopian barleys include high tillering capacity; tolerance to barley shoot fly and aphids; vigorous seedling establishment; and quick grain-filling. On the other hand, they tend to have weak straw, low grain-to-straw ratio, and fragile rachis (Hailu and Fekadu 1986).

المحيطة بهوليتا وشينو وبيكوجي. وقد تم تقييم المدخلات في محطات البحوث الواقعة في نفس المواقع الثلاثة. وتم تحفيز الأمراض باستخدام صنف حساس (أردو 12-8C) في كل المواقع، وبنثر مخلفات محصول مصاب (في هوليتا فقط). كانت السفحة (*Rhynchosporium secalis* (Oud.) J.J.Davis منتشرة في جميع المواقع الثلاثة، في حين كان التبقع الشبكي (*Pyrenophora teres* Drechs. [=*Drechslera teres* (Sacc.) Shoem.]) هاما في بيكوجي وموجودا أيضا في هوليتا. وقد تم انتخاب 60 سلالة مقاومة أو متوسطة المقاومة لكلا المرضين من كل موقع جمع، ثم زرعت في تجارب لتحديد الصفات الزراعية، واتضح أن هناك اختلافاً كبيراً في عدد الأيام حتى الإسبال وعدد الأيام حتى النضج وطول النبات مما يظهر إمكانية انتخاب سلالات نقية متكيفة مع أية بيئة خاصة.

Most farmers in Ethiopia use their own varieties (landraces). These landraces are heterogenous mixtures that have gone through natural selection for centuries. Farmers do not apply fertilizer, herbicides or insecticides and use minimum seed-bed preparation and weeding. Farmers may get sufficient yield for their subsistence and therefore have little inclination to use improved cultivars or high-input practices.

The composition of landraces may differ from locality to locality. Some components of landraces may have good yield potential with resistance to prevailing diseases and pests. Improved cultivars out-yielded the landraces when receiving good management under experimental conditions, but landraces are usually the highest yielders under low-input conditions. This paper presents the results of a study conducted to assess the amount of variation for disease resistance and agronomic characters, and to select pure lines for subsequent studies.

Material and Methods

The material used in this study was retrieved from the Plant Genetic Resource Center of Ethiopia (PGRC/E). A collection of 180 landraces from agro-ecological zones similar to the Holetta, Sheno and Bekoji areas was evaluated. Altitude and rainfall data of these three research stations are summarized in Table 1. Each accession was planted in observation plots of two rows, 2.0 m long with 0.2 m between rows. Three rows of the scald-susceptible Ardu 12-8C were planted adjacent to each plot as spreader. Disease infection at Holetta was enhanced by distributing scald-infested stubble at the 2–4 leaf stage.

Table 1. Altitude and rainfall pattern of the experimental sites.

Collection site	Administrative region	Altitude (m)	Rainfall season (mm)	Rainfall distribution (months)
Holetta	Shoa	2400	816	June–Sept
Sheno	Shoa	2750	735	July–Sept
Bekoji	Arsi	2810	907	June–Oct

At each station, the experiment was carried out both under fertilized (28.5 kg N/ha and 28.75 kg P_2O_5/ha) and unfertilized conditions.

Observations were made on scald, net blotch and other leaf diseases. Each disease was recorded twice, at one-month interval, with the first about seven weeks after planting. Each disease was recorded using a 0–9 double digit; only the last recording is considered here. Plant height (excluding awns) at maturity, days to 50% heading, and days to 50% maturity were also measured.

An analysis was performed for each agronomic character to estimate variation among testing locations and collection sites.

Finally, 60 accessions were selected and 20 heads were collected at random from each of the selected accessions. The 1200 heads were multiplied at Holetta during the off-season of 1989 and subjected to a series of yield, disease and pest evaluations from 1989 onwards.

Results and Discussion

A summary of disease readings on the 180 populations is given in Table 2. Scald was the most prevalent disease in all locations. Net blotch was important at Bekoji, with some infection also recorded at Holetta. Spot blotch (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem.]) was recorded on only a few populations at Holetta and Bekoji (data not shown). Leaf rust (*Puccinia hordei* Otth) was recorded only at Sheno. Reaction of populations was R–MR with percentage infection of <1–50 in both fertilized and unfertilized conditions. Only data on scald and net blotch are reported here.

All diseases were more severe on fertilized plots than on unfertilized ones. This is probably associated with the increased canopy development in fertilized plots during the early part of the season.

Table 2. Evaluation of 180 barley landraces for diseases, 1988/89. (Number of populations in each double digit disease category.)

Location	Fert†	Disease	0/t‡	11–19	21–29	31–39	41–49	51–59	61–69	71–79	81–89	91–99
Holetta	–	Scald	0	0	0	0	5	12	12	4	18	129
		Net blotch	53	0	0	0	28	36	49	13	1	0
	+	Scald	1	0	0	0	2	3	1	8	11	154
		Net blotch	0	0	0	0	1	4	7	2	14	152
Bekoji	–	Scald	1	0	0	0	1	11	8	11	18	130
		Net blotch	0	0	0	0	1	4	7	2	14	152
	+	Scald	0	0	0	0	0	0	0	0	0	180
		Net blotch	1	0	0	0	1	1	2	6	4	165
Sheno	–	Scald	11	26	34	24	30	17	28	9	0	1
	+	Scald	11	1	13	9	15	22	31	73	55	1

† Fertilizer application: – = Unfertilized; + = Fertilized.

‡ t = trace.

The mean agronomic data over 60 populations per collection site are given in Table 3. Significant variation was observed among collection and testing sites in days to heading and maturity. Landrace accessions collected from Holetta and Sheno had early heading and maturity dates. Early heading and maturity were recorded at Holetta with mean values of 86 and 137 days, respectively. Late heading and maturity were observed at Sheno and Bekoji. The variation for days to heading and maturity could be associated with the agroclimatic variation of the collection and testing sites. Fertilization led to earlier heading and maturity, with the largest difference at Bekoji.

There was also significant variation among collection and testing sites for plant height: plants were tallest at Bekoji and shortest at Sheno. Overall, fertilization increased plant height to an average of 117 cm, from 110 cm in unfertilized plots.

The diversity among collection and testing sites for agronomic characters (Table 4) can be interpreted as an indication of the possibility of identifying lines that can fit different growing environments.

Table 3. Agronomic characteristics of 60 populations per collection site.

Test location	Fertilizer	Collection site	DH	DM	PH
Holetta	–	Holetta	90	145	92.4
		Sheno	83	134	100.7
		Bekoji	94	145	94.5
		overall	89	145	95.8
	+	Holetta	82	134	127.4
		Sheno	82	134	99.7
		Bekoji	86	136	98.5
		overall	83	134	108.4
	Teting site mean		86	137	102.1
Sheno	–	Holetta	99	144	59.9
		Sheno	105	143	53.7
		Bekoji	106	153	65.9
		overall	103	147	59.8
	+	Holetta	97	137	82.0
		Sheno	99	137	75.5
		Bekoji	98	139	85.8
		overall	98	138	81.1
	Testing site mean		101	142	70.5
Bekoji	–	Holetta	101	145	106.9
		Sheno	98	155	113.3
		Bekoji	103	158	111.3
		overall	101	153	110.5
	+	Holetta	86	141	119.0
		Sheno	88	144	116.0
		Bekoji	89	145	116.1
		overall	87	143	117.1
	Testing site mean		94	148	113.8

Fertilizer application: – = Unfertilized; + = Fertilized.
DH = Days to heading; DM = Days to maturity; PH = Plant height (cm).

Table 4. Summary of ANOVA (mean squares) for three agronomic characters.

	d.f.	Heading date	Maturity date	Plant height
Locations	2	18396.32**	10454.29**	180733.50***
Fertilizer × location	3	7276.20***	6796.51***	19515.80***
Source × fertilizer	12	649.83***	1202.38***	3698.63***
Within Sources	1062	99.39	107.27	1206.37
CV (%)		12.84	8.33	42.18

** $P<1\%$; *** $P<0.1\%$.

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Importance and Control of Barley Leaf Blight in Turkey

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Abstract

Net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]), scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) and barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) are important leaf diseases of barley (*Hordeum vulgare* L. subsp. *vulgare*) in Turkey. Crop loss assessments from these diseases are estimated at between 5 and 50%. *Puccinia* spp. and *R. secalis* are the most destructive diseases. They occur on barley plants almost every year, but their intensity varies from year to year.

أهمية أمراض لفحة الأوراق على الشعير ومكافحتها في تركيا

الملخص

يعتبر مرض التبقع الشبكي (*Pyrenophora teres* Drechs. [=*Drechslera teres* (Sacc.) Shoem.]) والسفحة (*Rhynchosporium secalis* (Oud.) J.J.Davis) وتخطط الشعير (*Pyrenophora graminea* S.Ito & Kuribay. [=*Drechslera graminea* (Rab.) Shoem.]) أمراضاً هامة تصيب أوراق الشعير (*Hordeum vulgare* L. subsp. *vulgare*) في تركيا. ومن أكثر الأمراض خطورة *Puccinia* spp. و *R. secalis*. وهذه الأمراض تصيب نباتات الشعير كل عام تقريباً، إلا الإصابة تتباين من سنة لأخرى.

Key words: *Hordeum vulgare*; barley; disease control; *Pyrenophora teres*; *Rhynchosporium secalis*; *Pyrenophora graminea*; *Puccinia*; Turkey.

Crop losses

Table 1. Crop loss assessments due to barley leaf blight diseases in Turkey.

Disease	Crop losses (%)
Rust (*Puccinia* spp.)	20-50
Barley stripe (*Pyrenophora graminea*)	12
Net blotch (*Pyrenophora teres*)	12
Scald (*Rhynchosporium secalis*)	20
Powdery mildew (*Erysiphe graminis* f.sp. *hordei*)	5-30

Scald

Scald is important in the Erzurum region. Studies on *R. secalis* isolated from barley plants in Erzurum have revealed that the fungus survives through winter as stromata in infected plant debris; conidia do not survive the winter. Infected seeds have no role in the transmission of the disease. Benomyl (Benlate) seed treatment is effective in lowering *R. secalis* infections up to the seedling stage, but not at the flag-leaf stage. Benomyl spray is effective in controlling scald when applied to the foliage at seedling and flag-leaf stages (Döken 1979).

Barley cultivar Yeşilköy 6678 is being used to study the resistance mechanism to *R. secalis*. Leaf washings and intercellular fluid from the susceptible cultivar Tokak stimulated the germination of conidia of *R. secalis*, while conidial germinations were partly retarded when Yeşilköy 6678 was used. However, germination of conidia and appressorium formation on leaves of Yeşilköy 6678 were as on the susceptible cultivar, i.e. not influenced by the resistance of Yeşilköy. The resistance appears during the penetration of the cuticle or at the onset of subcuticular development. The cuticle as a physical barrier does not determine resistance unless through antifungal substances present in cuticular layers or possibly in the outer epidermal walls (Döken 1981).

There was also a histological study at the Plant Protection Research Institute to investigate host-pathogen relations in scald.

Barley stripe

Infection frequencies of barley stripe found in farm surveys were 3.3, 4.7 and 4.2%, respectively in 1984, 1987 and 1988, and 9.4, 2.3 and 6.2% in 1989, 1990 and 1991 (Damagacı and Aktuna 1988; Tunalı 1992). Physiological strains of *Pyrenophora graminea* and stripe-resistant cultivars of barley were identified. Biology and sporulation conditions were also studied by Tunalı (1992).

Net blotch

In Central Anatolia, the frequency of net blotch was 13.4% in 1984. Eight barley cultivars were moderately resistant to *P. teres* (Aktaş 1987). Iso-octyl ester, 2,4-D, fenoxaprop-ethyl, thifensulfuron + tribenuron methyl, and *Xanthium strumarium* significantly reduced the number of conidia of *P. teres* (Çetinsoy 1991, 1995).

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Herbicide and *Xanthium strumarium* Action on the Growth of *Pyrenophora teres in vitro*

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Abstract

A number of herbicides and water-extract of fruit of *Xanthium strumarium* L. were tested for their effects on mycelial growth and conidial development of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.), the causal agent of net blotch in barley (*Hordeum vulgare* L. subsp. *vulgare*), *in vitro*. Only fenoxaprop-ethyl (at 0.39 p.p.m.) and the *X. strumarium* extract significantly reduced sporulation. No other significant effects were recorded for number of septa, or dimensions or production of conidia, although some treatments prevented production of septa on conidia and evoked plasma-membrane abnormalities.

Key words: *Hordeum vulgare*; barley; *Pyrenophora teres*; *Xanthium*; herbicides; *in vitro* culture.

Introduction

Pyrenophora teres is a problematic pathogen of barley in Turkey. However, little work has been done on the effects of chemicals and weed extracts on growth of *P. teres*. Hodges (1977) examined 2,4-D and other auxin-like post-emergence herbicides for their influence on conidial germination, germ-tube growth and conidial production of *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. (= *Bipolaris sorokiniana* (Sacc.) Shoem.). He found that germination of conidia was not affected by the herbicides used, and that 2,4-D increased conidial production at higher concentrations and stimulated vegetative growth.

Material and Methods

The herbicides 2,4-D iso-octyl ester 48%, tribenuron-methyl 75%, fenoxaprop-ethyl 7.88%, thifensulfuron-methyl 50% + tribenuron-methyl 25%, and the water extract of the fruit of *Xanthium strumarium* (Sharma and Nathawat 1987) were tested for their effect on the *in-vitro* growth of *P. teres*. These herbicides are some of those already in use in grain fields in Turkey. The dosages used were 5.46 p.p.m. for 2,4-D iso-octyl ester, 0.037 p.p.m. for tribenuron-methyl, 0.39 p.p.m. for fenoxaprop-ethyl, and 0.093 p.p.m. for thifensulfuron-methyl + *tribenron-methyl*; the water extract of *X. strumarium* was diluted six times. A randomized block design was used with six replicates for mycelial growth and five replicates for conidial evaluation. Mycelial growth of a highly virulent local strain, T_4, of *P. teres* was measured on potato dextrose agar (PDA). For each replicate, 19 ml PDA was put into each petri dish and 1 ml of the solution to be tested was added. After inoculation with mycelial disks, the petri dishes were kept under light/dark periods of 12 h in an incubator at 21±1°C (Aktaş 1987). The growth of *P. teres* mycelium was noted after 3 and 7 days by measuring the diameter of the cultures, and mycelial growth per day was calculated for each replicate. Water agar (1%) was used to determine the effects of herbicides and water extract on numbers, septa numbers, length and width of conidia. For each replicate, 1 ml herbicide or extract solution was added to 19 ml water agar (1%) and poured into petri dishes, by treatment. After inoculation with a mycelial disk, petri dishes were kept under room conditions until the mycelial mass covered the whole dish (Tunalı 1992). The dish was then washed twice with 20 ml distilled water and number of conidia in a sample of 1 ml was recorded. These counts were made three times for each replicate. For each character, the number of septa and the width and length of 100 conidia were determined.

Results and Discussion

The effects of the herbicides and the weed extract on number of septa, and widths, lengths and production of conidia by *P. teres* are given in Table 1. Differences between treatments on septa

تأثيرات المبيدات العشبية و *Xanthium strumarium* على نموات *Pyrenophora teres* في المختبر

الملخص

تم في المختبر، اختبار تأثيرات عدد من المبيدات العشبية والمستخلص المائي لثمار *Xanthium strumarium* L. على النموات الفطرية الكونيدية لـ *Pyrenophora teres* Drechs (=*Drechslera teres* (Sacc.) Shoem.) .. العامل المسبب للتبقع الشبكي على الشعير (*Hordeum vulgare* L. subsp. *vulgare*) ولم يخفض التبوغ بشكل كبير سوى ايتيل فينوكسابروب (بتركيز 0.39 جزء بالمليون)، ومستخلص *X. strumarium*. ولم تسجل تأثيرات أخرى هامة بالنسبة لعدد الحواجز أو أبعاد أو إنتاج الأبواغ الكونيدية، رغم أن بعض المعاملات حالت دون إنتاج الحواجز على الأبواغ الكونيدية وأحدثت تشوهات في غشاء البلازما.

numbers, widths and lengths of conidia were not significant. The effects of the herbicides and the weed extract on conidia numbers were also evaluated by using Abbott formula (Table 2). Fenoxapropethyl (0.39 p.p.m.) and *X. strumarium* decreased sporulation significantly (Tables 1 and 2). Differences between the control and tribenuron-methyl (0.037 p.p.m), 2,4-D iso-octyl ester (5.46 p.p.m.), and thifensulfuron-methyl + tribenuron-methyl (0.093 p.p.m.) were not significant (Table 1). Absence of septa, granular appearance and condensation of plasma membrane abnormalities occurred in response to treatment in some conidia; however, most conidia germinated.

Significant differences in mycelial growth did not occurr between treatments (Table 3).

Table 1. Septa numbers, widths, lengths and production of conidia by *Pyrenophora teres* on the concentration of herbicides and *Xanthium strumarium*.

Treatment	No. replicates	No. conidia/ ml	No. septa	Width of conidia (μm)	Length of conidia (μm)
2,4-D iso-octyl ester	5	116.6	2.41	15.02	52.90
Tribenuron-methyl	5	131	2.12	16.09	54.21
Fenoxaprop-ethyl	5	88.8*	2.21	15.20	52.32
Thifensulfuron-methyl + tribenuron-methyl	5	99.6	2.56	15.66	57.59
Xanthium strumarium	5	82.2**	2.43	14.93	54.01
Check	5	135.6	2.47	16.45	58.65

*, ** Significant differences from check at P=0.05 and P=0.01, respectively, by Duncan's Multiple Range Test.

Table 2. The effects of herbicides and *Xanthium strumarium* extract on conidia numbers of *Pyrenophora teres*, using Abbott formula.

Treatment	Redn. conidia (%)
2,4-D iso-octyl ester	11.31
Tribenuron-methyl	6.74
Fenoxaprop-ethyl	35.05**
Thifensulfuron-methyl + tribenuron-methyl	27.34*
Xanthium strumarium	36.32**
Check	

*, ** Significant differences from check at P=0.05 and P=0.01, respectively, by Duncan's Multiple Range Test.

Table 3. The effects of herbicides and weed water extract on the mycelial growth of *Pyrenophora teres*.

Treatment	Mycelium diameter (cm)		Growth rate (cm/day)
	Day 3	Day 7	
2,4-D iso-octyl ester	2.13	5.15	0.75
Tribenuron-methyl	2.05	4.39	0.829
Fenoxaprop-ethyl	1.98	4.78	0.7
Thifensulfuron-methyl + tribenuron-methyl	1.96	5.18	0.80
Xanthium strumarium	1.36	4.3	0.73
Check	2.0	5.0	0.75

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Interaction Between Barley and *Pyrenophora graminea*: An Overview of Research in Italy

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Abstract

Since the late 1960s, the introduction of autumn-sown barley (*Hordeum vulgare* L. subsp. *vulgare*) cultivars has led to a great expansion in the cropping area in Italy, especially in the north. The main constraint to this expansion has been barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]); the cost of seed dressing against stripe in Italy in 1990 was nearly US$ 2.5 million. The disease is only transmitted through the seed, so dressing is essential. Italian barley seed falls into three categories: (1) certifiable, (2) certifiable only after dressing, and (3) uncertifiable. In virulence studies, *P. graminea* isolates could be divided into four groups. Barley resistance to *P. graminea* is complex, involving both a 'horizontal' multigenic component and 'vertical' mono- or oligo-genic one. Toxin isolated from *P. graminea* is heat-stable at 115°C for 15 min., anionic and of high molecular weight. Some strains of *P. graminea* are incompatible, as shown by lack of mixing in joint culture.

Key words: *Hordeum vulgare*; barley; *Pyrenophora graminea*; seed dressing; Italy.

Historical background

Until the 1960s barley was grown mainly in areas with poor fertility in southern Italy, where together with winter grazing the modest yields of grain and straw enabled farm families to survive. In such a socio-economic context advances in crop breeding and management were largely, if not entirely, lacking, and the country's average yield was low (Table 1). This situation changed completely in the late 1960s, when experiments showed that several autumn-sown barley cultivars were competitive with bread wheat (*Triticum aestivum* L. subsp. *aestivum*) and durum wheat (*T. turgidum* L. subsp. *durum* (Desf.) Husn.). This resulted in the crop's rapid spread into fertile areas of northern Italy.

Several factors caused this change in barley's fortunes. Foremost among them were the crop's easy field management and the steady market demand of the Italian feed industry, which takes 3 million tonnes/year (cf. 200,000 t for malting and 75,000 t for direct human consumption). Another factor was the

Table 1. Harvested area and yield of barley in Italy, 1960–1992.

Year	North		Center		South and Island		Total	
	(ha)	(t/ha)	(ha)	(t/ha)	(ha)	(t/ha)	(ha)	(t/ha)
1960	24,129	1.7	43,396	1.3	138,684	0.9	216,369	1.1
1972	40,445	3.1	54,257	2.2	91,762	1.6	184,464	2.1
1992	183,015	5.2	92,911	3.8	158,941	2.4	434,579	3.9

التآثر بين الشعير و *Pyrenophora graminea* : استعراض البحوث في إيطاليا

الملخص

منذ الستينات، أدى إدخال أصناف الشعير (*Hordeum vulgare* L. subsp. *vulgare*) التي تزرع في الخريف إلى توسع كبير في المساحات المزروعة بها في إيطاليا، ولاسيما في الشمال. ويعتبر تخطط الشعير (*Pyrenophora graminea* S.Ito & Kuribay. [=*Drechslera graminea* (Rab.) Shoem.]) العائق الرئيسي لهذا التوسع. وقد بلغت تكاليف تعقيم البذور للقضاء على مرض التخطط في إيطاليا في عام 1990 حوالي 2.5 مليون دولار أمريكي، علماً أن المرض لاينقل إلا بواسطة البذور، لذلك يصبح التعقيم أمراً أساسياً. تنقسم بذور الشعير الإيطالي إلى ثلاث فئات : (1) مصدقة، (2) مصدقة فقط بعد التعقيم و(3) غير مصدقة. وفي دراسات الفوعة، يمكن تقسيم عزلات *P. graminea* إلى أربع مجموعات، إن مقاومة الشعير لـ *P. graminea* معقدة، إذ يشارك فيها كل من المكون المتعدد المورثات 'الأفقي' والمكون الوحيد المورثة 'العامودي'. إن المادة السامة المعزولة من *P. graminea* مستقرة الحرارة عند 115م لمدة 15 دقيقة، وذات وزن جزيئي عال أنيوني. وإن بعض سلالات *P. graminea* غير متوافقة كما يتضح ذلك من عدم الامتزاج في مستنبت مشترك.

introduction, made possible by the crop's earliness, of barley–soybean and barley–maize double cropping by using barley for silage or grain. This resulted in an increase of barley area even in the irrigated lowlands. The direct use of barley grain by farmers as livestock feed, in the form of meal and flakes blended with other ingredients, and the growing of malt barley for a rising beer demand were also important (3.3 L/person per year in 1950; 26 L/person per year in 1980).

The ability of barley to meet the many demands of a modern, dynamic agriculture was largely due to the yield potential offered by the breeding of new cultivars. In 1960, the year that saw barley's resurgence in Italy, 67% of the barley area was in southern Italy. Modern spring cultivars helped the crop's resurgence, but barley's real competitiveness came with the release of autumn-sown, cold-resistant cultivars.

It was a widely-held belief in Italy at the time that spring cultivars from northern Europe could be used for autumn sowing. Although this was true for some areas of southern Italy, it proved not to be so elsewhere in the country. With the introduction in the 1970s of the first autumn cultivar, 'Maris Otter' from the United Kingdom, followed by 'Perga' from Germany, 'Ager' from France and others, the viability of autumn sowing in fertile environments with suitable cultivars became established. This led to a rapid shift in barley growing from marginal areas to fertile lowlands, where it now covers about 500,000 ha, and to the replacement of most spring varieties with the consistently higher-yielding autumn ones, although in the milder, more Mediterranean environments the autumn-sown spring varieties are still important.

The spread of barley between 1972 and 1990 has been a major success. There has been a four-fold increase in area in the north and a two-fold one in the center and south; at the same time yields have increased by 2.1, 1.5 and 0.9 t/ha in the same areas. The use of certified seed increased from 26% in 1972 to 90% in 1990 (Table 2).

Table 2. Certified seed of barley (tonnes) in Italy.

Year	Domestic production			Imports
	2-row	6-row	Total	
1972	2,243	3,487	5,331	356
1990	19,813	33,687	53,500	8,322

Constraints

The expansion of barley has had problems, especially in terms of seed-borne diseases which presumably were formerly sporadic. In the last 20 years, leaf stripe has become a serious threat to high-yielding but susceptible cultivars. However, the greatest hazard was the cold, humid environment of central and northern Italy. The problem was further complicated by the banning of the organo-mercurial compounds originally employed to combat the pathogen. 'Tania,' a German cultivar, yielded high in the recommended list trials as long as it was treated with organo-mercurials. Thereafter, seed multiplication in Italy without dressing showed its susceptibility to leaf stripe which reduced its yield potential. However, when dressed with systemic carboxin + thiram, it was once again high yielding. The economic impact of this disease (as well as other seed-borne diseases) is illustrated by the cost of seed dressing which was US$ 2.48 million in 1990.

Low temperatures and high relative humidity are important environmental factors in the onset and spread of leaf stripe. Tekauz et al. (1985) and Teviotdale and Hall (1976) found that the main spread of the disease coincides with soil temperatures below 15°C. Prasad et al. (1976) report that diurnal temperatures of 6–14°C and higher nocturnal ones accelerate pathogen onset, and that the coleoptile growth stage from elongation to soil emergence is critical. Trials conducted in Italy confirmed these findings (Table 3). Other factors, such as soil pH, light intensity and duration, soil status and moisture, can adversely affect germination and emergence and hence increase the disease incidence.

Table 3. Effect of sowing–brairding duration on the percentage of *Pyrenophora graminea* field infection and grain yield loss.

Temperature (°C)	Sowing–brairding duration (days)	Diseased plants (%)	Grain yield loss (%)
2.1	37	28	34
7.3	8	18	17
4.1	29	28	34
-1.6	64	51	45
7.1	15	24	19

As the disease is transmitted entirely by seed, seed analysis is a crucial factor. More than 50% of all the seed samples analyzed in Italy had infection rates higher than 10% (Porta-Puglia and Vannacci 1983). There are no indications that this situation has changed substantially. Knowing the percentage of infected seed and the relation between seed and plant infection is useful for estimating yield losses and adopting timely control measures.

Porta-Puglia et al. (1986) showed a notable drop in inoculum effectiveness from seed to coleoptile, a fact that markedly affects yield loss, and a further, but less pronounced, drop in effectiveness from coleoptile to culms (Table 4). Seed infection rate is highly correlated with (r = 0.90), but not directly related to yield loss.

Table 4. Percentage of infection of seedlings and tillers, and grain yield of infected seed samples.

Level of seed infection (%)	From seed to seedlings (%)	From seed to tillers	Grain yield (t/ha)
0	0.3	0.5	5.74
2	1.3	1.0	5.55
18	5.8	5.0	5.14
28	15.1	7.0	4.70
54	25.1	22.0	4.30
75	28.4	22.7	4.17
$LSD_{0.05}$	5.4	2.1	0.26

Control of barley stripe by seed-dressing is essential, but the effectiveness of dressing depends on the level of the seed infection (Table 5). The yield increment with treated infected seed is negligible at low infection levels but rises to nearly 1.1 t/ha when seed infection is high. However, despite the fact that this increase is proportional to infection percentage, maximum production cannot be obtained for seed which is more than 30% infected.

Table 5. Effect of chemical seed dressing on grain yield (t/ha) of barley.

Level of seed infection (%)	Non-treated	Treated
2	5.8	5.8
8	5.7	5.8
18	4.9	5.7
30	4.8	5.6
50	4.5	5.5
80	4.3	5.4
Mean	5.0	5.6
$LSD_{0.05}$	2.3	

Source: Delogu et al. (1987).

These findings were used to determine three seed classes: (A) certifiable without dressing (infection levels up to 14%), (B) certifiable only with dressing (14–30% infection), and (C) uncertifiable (over 30% infection). It should be noted that for pedigree seed production, dressing is indispensable regardless of infection level (Fig. 1).

A different approach to controlling this pathogen, although compatible with the former, is to identify sources of resistance for use in breeding programs. For this, one has to know both *host and pathogen* genetic variability. The data reported in the literature indicate the existence of post-penetration reaction mechanisms in the plant that prevent pathogen colonization, as well as others that may reduce pathogen development within the plant or even some that prevent seed infection. Although resistance genes have been identified (*Rhg1*, *Rhg2* and *Rhg3*), their localization on the chromosome and the number of alleles per locus (Søgaard and von Wettstein-Knowles 1987) have not.

We began by evaluating the responses of the most widely grown barley cultivars in Italy to a pathogen population originating from naturally infected seed of the variety Perga (Delogu et al. 1989). Percentage of infected seed (determined in a single environment), transmission index (percentage ratio of infected plants to infected seed, over five environments) and tolerance index (percentage ratio of partially colonized plants to overall infected plants over five environments) were recorded. Variation occurred for all parameters. Genotypic differences were highly significant, while the environment effect was significant only for the transmission index. This confirms the importance of the length of time between sowing and emergence for the pathogen's ability to pass from seed to plant. The genotype × environment interaction, albeit significant, proved only of minor interest because of its small absolute value.

The ranges of individual parameters among the cultivars are given in Table 6. They were not correlated with one another. The transmission index made it possible to divide the cultivars in four groups (Table 7). It had a high broad-sense heritability ($h^2 = 0.88$) whereas the heritability of the tolerance was lower ($h^2 = 0.46$). Of the cultivars examined, the six-row Onice, Opale and Criter and the two-row Alpha, Jeff, Nico and Tipper exhibited high resistance under natural infestation in the field. These findings show that the barley plant can deploy resistance mechanisms at three growth stages: (i) kernel formation, by preventing its colonization by the fungus, (ii) germination, by combating coleoptile penetration, and (iii) growth, by preventing colonization of the adult plant.

Table 6. Percentage of seed infected by *Pyrenophora graminea*, index of transmission and index of tolerance. Range and mean value of 30 barley varieties.†

	Freq. infected seed (%)	Index of transmission‡	Index of tolerance§
Range	55–79	0.00–0.78	0.00–0.54
Mean	68	0.22	0.30
$LSD_{0.05}$	16	0.08	0.15

† Grown at five environments.
‡ Ratio of infected plants to infected seeds.
§ Ratio between the number of plants partially affected and the total number of infected plants.

To study the fungus population, 12 isolates of *P. graminea* (*Dg1–Dg12*) were used. The isolates were obtained from infected two-row and six-row barley fields in eight Italian locations and were morphologically characterized.

Table 7. Distribution of 30 winter barley varieties in groups with different levels of resistance to *Pyrenophora graminea* as determined by the indices of transmission.

Group†	No. varieties	Index of transmission‡		Av. freq. infected seeds (%)
		Mean	Range	
HR	8	0.03	0.00–0.05	68
R	3	0.10	0.08–0.11	63
MR	9	0.18	0.12–0.26	68
S	10	0.44	0.31–0.78	70
$LSD_{0.01}$				12

† HR = highly resistant; R = resistant; MR = moderately resistant; S = susceptible.
‡ Ratio of infected plants to infected seeds.

Pathogenicity tests on a set of widely grown barley varieties confirmed the existence of wide variability in virulence and the presence of biotypes within the *Dg* population (Table 8). The "sandwich" inoculation technique tests for resistance at the time of coleorhiza penetration at the onset of infection. The pathogen response was host-specific, e.g. cv Thibaut was resistant to all the isolates except *Dg5*, whereas Gerbel, Jaidor and Aramir were resistant to *Dg5* but not to *Dg2*.

These findings suggest a rather complex multi-genic, 'horizontal' resistance system, on top of which a 'vertical' mono- or oligo-genic system is operating. Variability in virulence is accompanied by phenotypic variability in electrophoretic patterns of fungal protein extract (Table 9). As no correlation can be determined between electrophoretic patterns, virulence or other phenotypic traits, this fact implies a heterokaryosis when taken together with the large number of nuclei per cell.

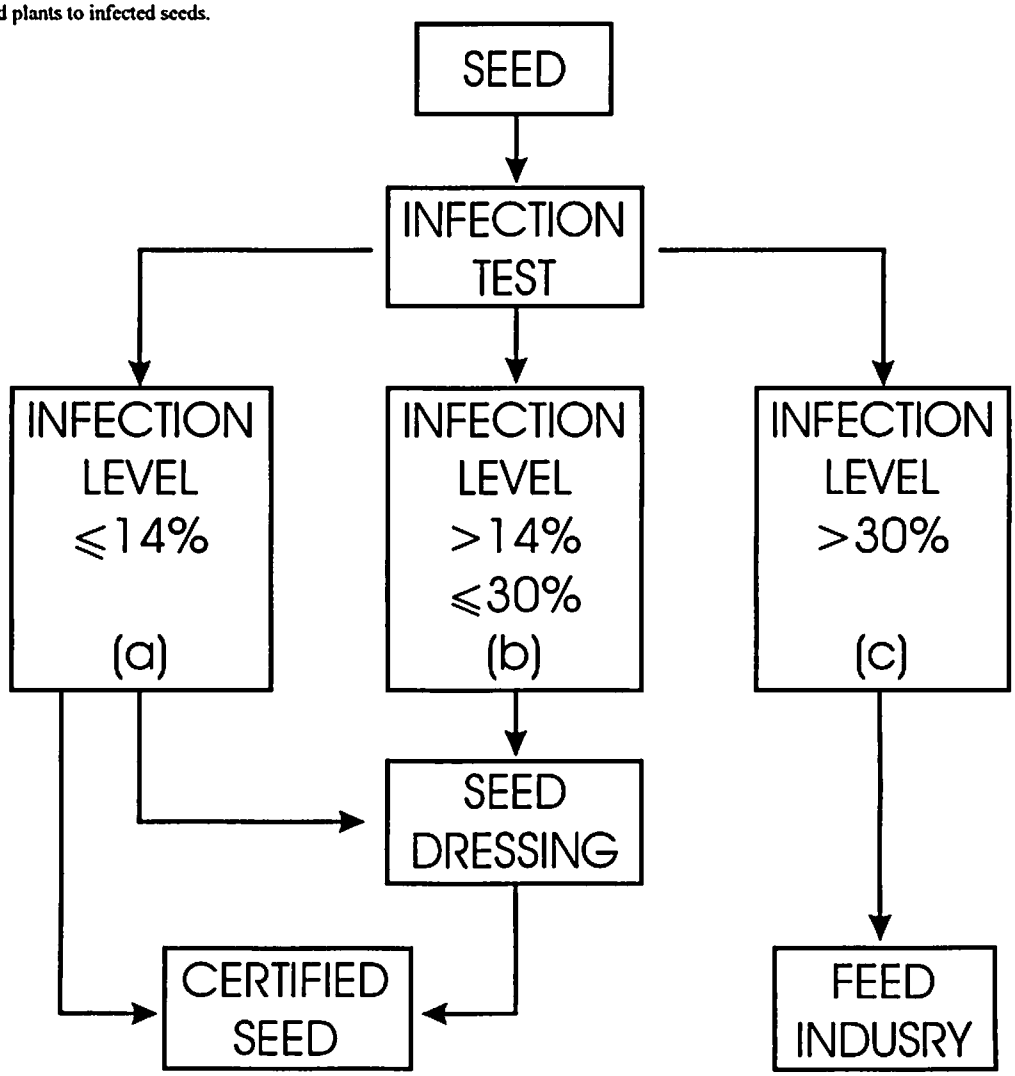

Figure 1. Protection strategies for seed certification. Three seed classes are represented: (a) certifiable without dressing (infection level up to 14%); (b) certifiable only with dressing (14–30% infection level); (c) uncertifiable (over 30% infection). For varietal purity conservation, seed dressing is indispensable regardless of infection level.

Table 8. Percentage infection of barley seedlings of 19 barley varieties artificially inoculated with 12 *Pyrenophora graminea* isolates.

Barley var.	Isolate												Mean
	Dg2	Dg5	Dg10	Dg8	Dg18	Dg12	Dg19	Dg9	Dg3	Dg13	Dg6	Dg7	
Two-rowed													
Arda	27	7	7	47	1	5	0	0	0	0	0	0	8
Aramir	56	0	61	49	0	3	5	0	0	0	0	0	15
Alpha	21	29	11	6	5	0	0	1	2	0	2	2	7
IGRI	21	21	7	11	0	0	0	1	0	0	0	0	5
Kaskade	55	39	57	56	4	35	17	0	0	0	0	0	22
Panda	73	84	10	24	35	0	6	0	0	0	3	0	20
Tipper	9	0	0	1	0	0	0	10	0	0	1	0	2
Zita	12	8	15	5	1	1	0	0	0	0	0	1	4
Six-rowed													
Barberousse	62	72	0	59	0	77	15	33	0	12	0	2	28
Etrusco	71	42	83	43	83	23	57	0	0	0	1	0	34
Gerbel	80	0	37	62	0	0	38	0	0	0	0	0	18
Jaidor	80	0	42	33	54	68	0	6	0	0	0	0	24
Mirco	90	84	89	39	31	59	56	0	24	0	0	4	40
Novo Perga	87	67	40	65	0	0	3	0	0	6	0	0	22
Onice	4	0	0	8	0	0	0	2	0	0	0	0	1
Robur	77	62	23	6	26	5	0	0	0	2	2	0	17
Selvaggio	66	45	50	55	54	5	30	49	0	0	9	0	30
Tania	35	25	10	26	0	3	21	1	0	0	0	1	10
Thibaut	4	82	5	1	0	1	3	3	0	3	0	1	9
Mean	49	35	31	29	16	15	13	6	1	1	1	1	0

LSD (0.01) (Value in arcsin √%) Variety (V) = 4; Isolates (I) = 3; Interaction (V × I) = 13.

Our current work is focused on four topics: (i) transfer of resistance via the pedigree method, i.e. natural field inoculation with a susceptible spreader in all progeny generations subjected to selection and artificial inoculation in glasshouse via the 'sandwich test;' (ii) the use of fungus-produced toxins; (iii) pathogen population structure; and (iv) the plant's molecular response to attack.

Pyrenophora graminea is taxonomically close to other pathogens known for producing host-specific toxins. Its toxin, as found in the culture filtrates, is heat-stable at 121 °C for 15 min., polar (anionic) and has high molecular weight.

Other studies include the structure of populations with special emphasis on vegetative compatibility. Preliminary tests with dual-dish cultures of various pathogen isolates have found that several combinations show mycelial incompatibility along the line of contact between the two colonies. This phenomenon, due to the inability of the two isolates to form stable cytoplasmic links, may have some bearing on the spread of virulence genes between various populations. Other studies with isolates will involve reliable genetic markers using the polymerase chain reaction.

An experimental protocol has been developed to detect differences in the plant's molecular response to the pathogen. It uses two *Dg* isolates, one to elicit a susceptible reaction and the other to induce a reaction in the host that is so hypersensitive as to repel pathogen attack. The isolation of mRNA, *in-vitro* translation and the use of homologous and heterologous probes for genes known to be involved in the response to similar situations in barley and other species could lead to the characterization of the identification of the plant genes involved in the host–pathogen interaction.

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Table 9. Schematic representation of mycelium protein of *Pyrenophora graminea* isolates.†

Band no.	Dg2	Dg3	Dg5	Dg6	Dg7	Dg8	Dg9	Dg10	Dg12	Dg13	Dg18	Dg19
1	++	++	+	++	++	++	++	++	++	++	+	++
2	-	++	-	++	++	++	++	++	++	++	++	++
3	++	-	+	++	++	++	+	-	+	++	++	++
4	-	++	-	++	+	++	++	+	++	++	+	++
5	-	+	-	+	+	-	+	-	++	+	-	++
6	++	++	++	+++	++	++	++	++	++	+++	++	++
7	++	+++	++	+++	+	++	+++	+++	+++	+++	+++	++
8	+	++	++	+	+++	++	+	+	++	+	+	++
9	+	++	-	+++	-	+	-	+	++	++	+++	+++
10	-	++	-	++	-	++	-	-	++	-	++	++
11	+	++	++	++	++	++	+	++	++	+	++	++
12	++	+	++	++	++	++	++	++	++	++	++	++
13	-	++	-	-	-	++	-	-	-	-	-	-
14	+	++	+	++	++	++	++	-	++	+	++	++
15	-	-	-	-	-	-	-	++	++	-	++	++
16	++	++	-	++	-	++	-	++	-	-	++	++
17	-	-	-	++	-	-	-	-	-	-	++	++
18	-	++	-	-	++	++	++	-	++	++	++	++
19	-	++	-	++	-	-	+	-	-	-	++	++

The number of plus signs indicates the level of band intensity: +++ = strongly expressed; ++ = normally expressed; + = faint; - = absent.

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Selecting Sources of Resistance to *Cochliolobus sativus* under Subtropical Conditions and Preliminary Loss Assessment

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Abstract

In subtropical areas, where it is not a traditional crop, barley (*Hordeum vulgare* L. subsp. *vulgare*) needs to be adapted to hot conditions. It also needs to be resistant to the main biotic constraint, spot blotch (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. (= *Bipolaris sorokiniana* (Sacc.) Shoem.) [Syn. *Helminthosporium sativum* Pammel, King & Bakke]). Material from ICARDA/CIMMYT, China and North Dakota (USA) was evaluated. Several lines from the cross Gobernadora × Higuerilla "S" were comparable in disease resistance to BRB2 (Thai cultivar used as resistant check). Most of the lines from North Dakota were highly susceptible to *C. sativus*; the few moderately resistant ones were not adapted to heat, but may be used in combination with other sources of resistance. Strong negative correlations were evident between infection of various plant parts and yield and 1000-kernel weight.

Key words: *Hordeum vulgare*; barley; varieties; evaluation; disease resistance; *Cochliobolus sativus*; subtropical climate; adaptation.

انتخاب مصادر مقاومة *Cochliobolus sativus* تحت الظروف شبه الاستوائية والتقدير الأولي للخسائر

الملخص

في المناطق شبه الاستوائية يحتاج الشعير (*Hordeum vulgare* L. subsp. *vulgare*) . وهو محصول غير تقليدي فيها، إلى التكيف مع الظروف الحارة، كما يحتاج أيضاً إلى مقاومة العائق الأحيائي الرئيسي، التبقع الهلمنثوسبوري (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. (=*Bipolaris sorokiniana* (Sacc.) Shoem.) [Syn. *Helminthosporium sativum* Pammel, King & Bakke]).

وقد قيمت المواد الوراثية الواردة من إيكاردا/سيميت، الصين وداكوتا الشمالية (الولايات المتحدة). وكانت عدة سلالات ناتجة عن تهجين Gobernadora x Higuerilla "S" مساوية في مقاومتها للمرض لـ BRB2 (وهو صنف Thai المستخدم كشاهد مقاوم). وكانت معظم السلالات الواردة من داكوتا الشمالية حساسة للغاية لـ *C. sativus*؛ في حين لم تتكيف سلالات قليلة متوسطة المقاومة مع الحرارة، إلا أنها قد تستخدم بالاشتراك مع مصادر أخرى للمقاومة. وكانت هناك ارتباطات سلبية قوية واضحة بين إصابة مختلف أجزاء النبات والغلة ووزن الألف الحبة علماً أن هذه الأمور تحتاج إلى إثبات.

Introduction

One of the objectives of the joint Barley Program of the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) is to provide germplasm to national programs in warmer areas where barley is not a traditional crop, e.g. Thailand, Vietnam and Bangladesh in Asia, Uganda and Tanzania in Africa, and Brazil in South America. Barley germplasm for these areas needs to have acceptable resistance to *Cochliobolus sativus* and good adaptation to hot conditions.

In these environments *C. sativus* is one of the major biotic stresses limiting barley production. Although the pathogen can attack seedlings, crown and roots, damage is most severe on leaves, nodes, spikes and grain.

No information exists about resistant germplasm in these environments, with the exception of BRB2 and BRB9, Thai varieties released in 1987 and 1992, respectively. In temperate regions, several sources of resistance to *C. sativus* have been identified in the USA (Wisconsin, Minnesota and North Dakota) and Canada (Ontario) (Amy 1951; Banttari et al. 1975; Gonzalez 1990; Clark 1979).

The objectives of this work were to select material with resistance to the pathogen and, at the same time, select for adaptation to heat under subtropical conditions, and to obtain preliminary information on losses caused by the disease.

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Material and Methods

The germplasm was evaluated at Poza Rica, Mexico, a sub-tropical environment (Fig. 1) with high natural disease incidence.

The material tested was grown from 20 November to 15 March during two growing seasons (1990/91 and 1991/92). In the first year, 55 barley lines were evaluated. These were early-maturing barley lines developed by ICARDA/CIMMYT, Chinese germplasm with resistance to scab (*Fusarium graminearum* Schw.) and North Dakota cultivars with resistance to *C. sativus* under temperate conditions. In the second year, 23 F_5 lines and 72 F_6 lines were tested. These lines were derived from resistant parents with good adaptation identified in the first year of testing, and known to be scab resistant. The two resistant checks included were BRB2, a commercial Thai variety with malting quality and late maturity, and AKB2, an early-maturing resistant line but with poor plant type.

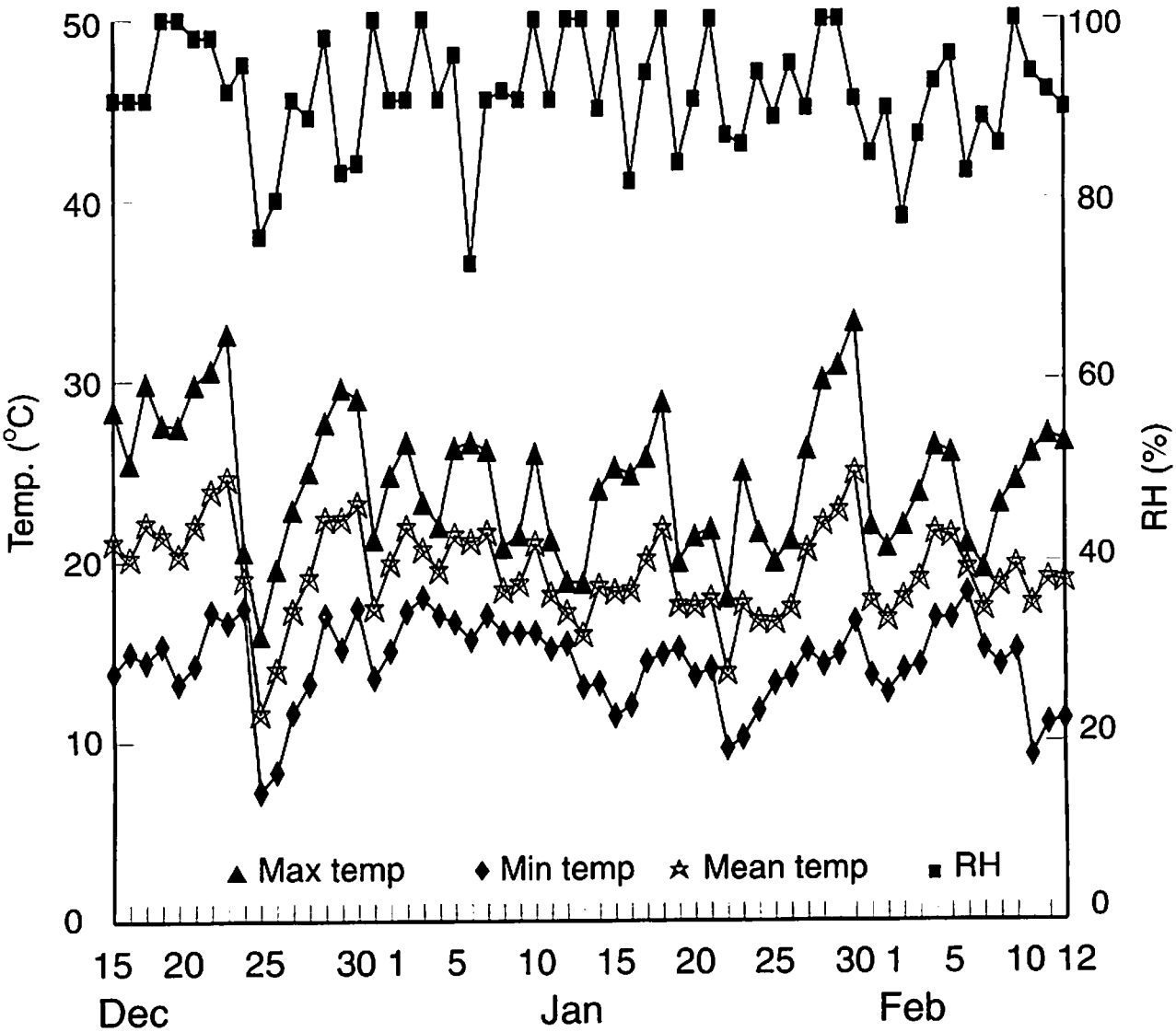

Figure 1. Temperature and relative humidity at Poza Rica, Veracruz, Mexico (20°32' N, 97°26' W, 60 m), 1990/91.

In the first year, each line was planted in one double-row 2-m long on two dates (23 November and 3 December). Two sets of each material were sown. One set was protected with fungicide (Folicur, a.i. = tebuconazole) and the second was subjected to heavy natural infection of *C. sativus*. In the second year, each line was planted in two double-rows 5-m long to facilitate selection of individual plants.

Leaf damage was recorded in the first year at growth stages 10.5.4 and 11.1 (Feekes-Large Scale). Infection was scored using a double-digit scale (Saari and Pescott 1975), and transformed to an infection coefficient which is the product of both digits. Infected grain (%), node infection (1 or 0), 1000-grain weight (TGW, g) and grain yield (g) were also recorded.

Phenotypic correlation estimates were derived using the CORR procedures of SAS computer program.

Results and Discussion

Four groups of lines possessing the following characteristics were clearly identified:

1. Acceptable heat tolerance and resistance to *C. sativus*.
2. Heat tolerant, but susceptible to *C. sativus*.
3. Poor adaptation to heat and susceptible to *C. sativus*.
4. Acceptable resistance to *C. sativus*, but poor adaptation to heat (very few lines).

In the ICARDA/CIMMYT lines, the information obtained from the first year gave an acceptable group of lines derived from the cross of variety Gobernadora with line Higuerilla "S". Gobernadora (Zhe Main 1) is widely cultivated in the Yang Tze basin of China (80,000 ha), because of its resistance to scab and tolerance to barley yellow mosaic virus (BYMV). Higuerilla "S" is an early-maturing barley which was scheduled for release in Kenya in 1993 for its resistance to barley yellow dwarf virus (BYDV) and its malting quality. Some of the lines derived from this cross were more resistant than the parents and comparable in resistance to the check variety BRB2 (Table 1). This level of resistance suggests the possibility of a transgressive segregation for two characters, foliar damage and black point. However, Monte and Wilcoxson (1989) studied the progeny derived from six crosses of barley resistant and susceptible to kernel damage, and observed transgressive segregation toward susceptibility to black point in F_3 populations of all crosses.

Higuerilla "S" has good heat tolerance (Table 2), but Gobernadora has some problems when the temperature rises above 28°C as in the second planting date (Fig. 1, end of January).

In the lines listed in Table 2, yield losses were moderate, compared with the check variety BRB2. The yield potentials of the lines when treated with fungicide were comparable with those of the BRB2 in both planting dates. Further improvement of the yield potential of these lines is needed.

The North Dakota material was not adapted to the subtropical environment and the majority of lines were susceptible to highly susceptible to *C. sativus* (Tables 3 and 4). In our experience, it is very difficult to see any expression of resistance in material not adapted to subtropical growing conditions. However, some of the lines showed moderate resistance and may be useful in combination with other sources. The lines with the best level of resistance to foliar damage in this group were ND 9528 and ND 10143. Less resistance was observed in ND 7556, ND 8650 and ND 9870, the latter showing more resistance to black point.

ND B112, which forms the base of spot blotch resistance in the Great Plains of the USA, showed very poor adaptation. It was also highly susceptible, but in some crosses with adapted germplasm resistance expression was enhanced.

Node damage and black point correlations were calculated from preliminary data on yield and 1000-kernel weight vs foliar damage at two stages (10.5.4 and 11.1; Table 5). Correlations were also obtained between the different infected plant parts: foliar damage at two stages, and node and grain damage (Table 6).

Table 1. Spot blotch (*Cochliobolus sativus*) scores for selected barley lines and their parents at Poza Rica, Mexico, planted on 23 November 1990.

No.	Line or Cross	FD1	FD2	ND	BP	KW	LS
1	HLLA"S"/GOB"S"//HLLA"S" CMB85-553-H-3Y-2B-0Y	7.2	7.3	0	1†	31.6	21
2	HLLA"S"/GOB"S"//HLLA"S"CMB85-553-H-7Y-1B-0Y	7.1	7.3	0	1†	33.5	21
2	HLLA"S"/GOB"S"//HLLA"S"CMB85-553-H-12Y-1B-0Y	7.3	7.5	0	1	32.0	18
4	HLLA"S"/GOB"S"//HLLA"S"CMB85-553-0-3Y-1B-0Y	7.1	8.5	0	2	33.4	20
5	HLLA"S"/GOB"S"//HLLA"S"CMB85-553-H-1Y-1B-0Y	7.3	9.3	0.5	2	31.9	19
6	GOB"S" CMB78-1176-B-3Y-1B-1Y-1B-OY	7.3	9.6	0	4	25.0	16
7	HLLA"S" CMSWB81A-425-A-1B-5Y-OB	7.4	9.5	0	2	35.2	21
8	BRB2 (Resistant check)	7.1	8.4	0	4	26.1	24
9	AKB2 (Resistant check)	7.1	7.1	0	1	30.0	1

FD1 = Foliar damage at growth stage 10.5.4 (00–99); FD2 = Foliar damage at growth stage 11.1; ND = node damage (0/1); BP = Black point; KW = 1000-kernel weight (g); LS = Losses (%).
† Good grain fill.

Table 2. **Reduction in 1000-kernel weight (g) in selected barley lines naturally infected with *Cochliobolus sativus* for two planting dates at Poza Rica, Mexico, 1990/91.**

Line or Cross	23 Nov			3 Dec		
	WF	WOF	LS	WF	WOF	LS
HLLA"S"/GOB"S"//HLLA"S" CMB85-553-H-1Y-1B-0Y	39.4	31.9	19	39.3	35.8	9
HLLA"S"/GOB"S"//HLLA"S" CMB85-553-H-3Y-2B-0Y	40.3	31.6	21	39.2	32.4	17
HLLA"S"/GOB"S"//HLLA"S" CMB85-553-H-7Y-1B-0Y	42.6	33.5	21	41.9	34.1	19
HLLA"S"/GOB"S"//HLLA"S" CMB85-553-H-12Y-1B-0Y	39.4	32.0	18	41.1	33.8	18
HLLA"S"/GOB"S"//HLLA"S" CMB85-553-0-3Y-1B-0Y	41.8	33.4	20	41.4	33.1	20
HLLA"S" CMSWB81A-425-A-1B-5Y-OB	44.6	35.2	21	48.1	44.1	8
GOB"S" CMB78-1176-B-3Y-1B-1Y-1B-1Y	29.8	25.0	16	0.0	0.0	100
BRB2 (Resistant check)	34.2	26.1	24	34.1	27.1	20
AKB2 (Resistant check)	31.1	30.7	1	30.2	33.0	0

WF = 1000-kernel weight with fungicide; WOF = 1000-kernel weight without fungicide; LS = Losses (%).

Table 3. **Spot blotch (*Cochliobolus sativus*) scores for North Dakota barley lines planted on 23 November 1990 at Poza Rica, Mexico.**

Line or Cross	FD1	FD2	BP	KW	LS
ND B112	9.5	9.9	–	–	100
ND 8650	7.3	8.6	4	22.9	25
ND 8671	8.5	9.9	–	–	100
ND 8803	8.6	9.9	–	–	100
ND 7556	7.2	8.7	4	26.6	27
ND 9528	7.2	8.4	4	28.3	14
ND 10143	7.2	8.4	4	33.4	18
ND 9870	7.3	8.5	2	32.1	14
ND 10270	7.3	9.7	–	–	100
ND 10277	7.3	9.7	–	–	100
BRB2 (Rest. check)	7.1	8.4	4	26.1	24
AKB2 (Rest. check)	7.1	7.1	1	30.7	1

FD1 = Foliar damage at growth stage 10.5.4 (00–99); FD2 = Foliar damage at growth stage 11.1; BP = Black point ; KW = 1000-kernel weight (g); LS = Losses (%).

Table 4. **Reduction in 1000-kernel weight (g) in North Dakota barley lines caused by natural *Cochliobolus sativus* infection at two planting dates at Poza Rica, Mexico, 1990/91.**

Line or Cross	23 Nov			3 Dec		
	WF	WOF	LS	WF	WOF	LS
ND B112	–	–	–	–	–	–
ND 8650	30.3	22.9	25	29.0	26.0	10
ND 8671	20.8	–	100	–	–	–
ND 8803	29.3	–	100	–	–	–
ND 7556	36.4	26.6	27	36.1	31.7	12
ND 9528	33.0	28.3	14	26.0	23.1	11
ND 10143	40.9	33.4	18	40.2	35.6	11
ND 9675	–	–	–	27.5	23.8	14
ND 9870	37.0	32.1	14	32.1	–	100
ND 10270	33.5	–	100	–	–	–
ND 10277	30.9	–	100	32.3	–	100
BRB2 (Rest. check)	34.2	26.1	24	34.1	27.1	20
AKB2 (Rest. check)	31.1	30.7	1	30.2	33.0	100

WOF = 1000-kernel wt without fungicide; WF = 1000-kernel wt with fungicide; LS = Losses (%).

Table 5. Correlation of yield and 1000-grain weight with coefficient of leaf infection (two growth stages), grain infection and node infection, Poza Rica, Mexico, 1990/91.

Disease	Feekes-Large growth stage	Yield	1000-grain weight
Leaf infection	10.5.4	-0.72***	-0.84***
	11.1	-0.68***	-0.73***
Grain infection	11.4	-0.44*	-0.60**
Node infection	11.2	-0.61**	-0.74***

*,**,*** significant at the 5%, 1% and 0.1% levels of probability, respectively.

Table 6. Correlation among disease scores for different plant parts at growth stages 10.5.4. and 11.1 in barley lines affected by *Cochliobolus sativus* for leaf, node and grain infection, Poza Rica, Mexico, 1990/91.

Disease	Feekes-Large growth stage	Leaf infection (at 11-1)	Node infection	Grain infection
Leaf infection	10.5.4	0.88***	0.67***	0.56**
	11.1		0.63***	0.69***
Node infection	11.2			0.43*

*,**,*** significant at the 5%, 1% and 0.1% levels of probability, respectively.

The analyses indicated a strong negative correlation between disease (foliar, node and black point) and yield and 1000-kernel weight. Studies carried out with bread wheat (*Triticum aestivum* L. subsp. *aestivum*) over three years indicated a similar effect of the disease on foliar and node damage, but no relationship or a very weak one was found for grain damage (Gilchrist et al. 1991).

A strong correlation was found among the three plant parts affected (Table 6). In this respect, Gilchrist et al. (1992) found that grain infection in wheat was not associated with leaf and node infection and it appears to be controlled by a different genetic system. Given the importance of elucidating these interactions, we were evaluating 125 barley lines in 1993 to confirm the preliminary findings.

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Barley Leaf Blights in Iran

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Abstract

In Iran, barley (*Hordeum vulgare* L. subsp. *vulgare*) is grown on about 2 million hectares, of which 68% is rain-fed. The aim of the Iranian barley program is to develop high-yielding cultivars which are widely adaptable and resistant to diseases and abiotic stresses. Scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) is common in the semihumid areas, causing yield losses up to 25%. Barley leaf stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) has recently become important in several areas, again with losses up to 25%. Spot blotch (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem.]) is common but unstudied. Net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) is presumed to be of negligible importance. The research program focuses on resistance breeding, with hot spots being used to screen material.

Key words: *Hordeum vulgare*; barley; genotype environment interaction; plant breeding; disease control; *Pyrenophora graminea*; *Pyrenophora teres*; *Cochliobolus sativus*; *Rhynchosporium secalis*; cultural methods; plant diseases; pathogens; Iran.

Introduction

Barley is an important crop grown in many ecological zones in Iran at different altitudes, in various climatic zones and under various soil conditions. It occupies about 2 million hectares, of which 68% is rain-fed; the remainder is under irrigation. Barley research is carried out by the Seed and Plant Improvement Research Institute, the Pest and Disease Research Institute, and the Soil and Water Research Institute. The main objective of the barley program is to develop high-yielding, widely adaptable cultivars with resistance to diseases and environmental stress. Research stations used for breeding and agronomic work are:

1. Karaj: Breeding of winter and intermediate barley varieties (this station coordinates all cereal breeding activities in Iran);
2. Gorgan: Breeding of spring barley varieties and pathological research;
3. Ahvaz and Shiraz: Breeding of spring barley varieties for irrigated highly fertile conditions;
4. Bakhtaran: Breeding of winter and spring barley varieties for rain-fed conditions.

لفحات الأوراق على الشعير في إيران

الملخص

تحتل زراعة الشعير (*Hordeum vulgare* L. subsp. *vulgare*) في إيران مساحة 2 مليون هكتار تقريباً، منها 68٪ زراعة بعلية. ويهدف برنامج الشعير الإيراني إلى استنباط أصناف مغلالة متأقلمة إلى حد كبير، ومقاومة أيضاً للأمراض والإجهادات اللا أحيائية. وتنتشر السفحة (*Rhynchosporium secalis* (Oud.) J.J. Davis) في المناطق شبه الرطبة مسببة خسائر في الغلة تصل إلى 25٪ كما أصبح في الفترة الأخيرة مرض تخطط أوراق الشعير (*Pyrenophora graminea* S.Ito & Kuribay.[=*Drechslera graminea* (Rab.) Shoem.]) هاماً في العديد من المناطق، مسبباً خسائر تصل إلى 25٪ أيضاً. وكذلك يعتبر مرض التبقع الهلمنثوسبوري (*Cochliobolus sativus* (Ito & Kurib.) Drechs.ex Dast. [=*Bipolaris sorokiniana* (Sacc.) Shoem.]) شائعاً، إلا أنه لم يدرس بعد، في حين يعتبر مرض التبقع الشبكي (*Pyrenophora teres* Drechs. [=*Drechslera teres* (Sacc.) Shoem.]) غير مهم. ويركز برنامج البحوث على التربية للمقاومة باستخدام المناطق الموبوءة لغربلة المواد.

The remaining (68) research stations and substations are used in testing and evaluation of regional trials and for agronomic trials. Released varieties include Walfajr, Rihane, Gouhar, Zarjo, Gorgan 4, Star, Kavir, Arass, Karoon, Shehr Kurd-L, Baluch-L, Mughan-L, Atlas-46 and Gorgan-L.

Barley pathology

The most important barley diseases in Iran are: scald, barley leaf stripe, spot blotch, and net blotch. Of less importance is the bacterial disease *Xanthomonas campestris* f.sp. *hordei*.

Scald

Scald is a common disease of barley, especially in the cooler semihumid barley-growing areas. It is widespread in the Caspian Sea (Gorgan, Gonbad), northwest (Azarbaijan, Moghan), south (Ahvaz) and northeast (Khorasan) regions.

Incidence and prevalence of scald are correlated with environmental conditions and cultivar. In the north, scald was epidemic in 1992. Gorgan 4 was susceptible and the local barley moderately susceptible to the disease. Yield losses were estimated at up to 25% for Gorgan 4 and 5–10% for the local barley.

Barley leaf stripe
In recent years, barley leaf stripe has become an important disease in various parts of Iran. The disease has been reported from the Caspian Sea area, Azarbaijan, Ahvaz, Mashad, Karaj, Zanjan and the west. Losses of 15–25% have been reported in Azerbaijan.

Spot blotch
Spot blotch on the leaves is widespread on barley in various parts of Iran. Little information is available on its effect on yield.

Net blotch
Net blotch does not seem to be important; however, between emergence and anthesis the disease is often severe on the lower leaves. Its impact on yield and yield components is not well documented in Iran.

Other diseases
Other diseases recorded in Iran are: leaf rust (*Puccinia hordei* Otth), yellow or stripe rust (*Puccinia striiformis* West.), powdery mildew (*Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal [= *Oidium monilioides* Desm.]), loose smut (*Ustilago nuda* (Jens.) Rostr.), covered smut (*U. hordei* (Pers.) Lagerh.) and barley yellow dwarf virus.

Research
Barley pathology research in Iran focuses on sources of resistance to the main diseases and evaluation of barley material generated by breeding projects. It uses multilocation testing and screening for disease resistance in hot spots.

Karaj station is the main center for barley breeding. Hot spots for barley diseases are Gorgan station (Caspian Sea area), for scald, leaf stripe and spot blotch; Klardsht and Gharkhil stations for yellow and leaf rusts; Moghan station for scald, barley stripe and rusts; and Ahvaz station for scald, barley leaf stripe and leaf rust. Western stations are suitable for smut evaluation as well as for spot blotch, barley leaf stripe and rusts.

Barley Leaf Blights in Cyprus

أمراض لفحة الأوراق على الشعير في قبرص

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Abstract

Barley (*Hordeum vulgare* L. subsp. *vulgare*) is the most important crop grown under rain-fed conditions in Cyprus. Foliar diseases are widespread but their economic importance has not been evaluated. Studies were initiated recently to examine the host × pathogen × environment interaction. Emphasis is on breeding and cultural practices for the control of barley diseases.

Key words: *Hordeum vulgare*; barley; plant breeding; cultural methods; disease resistance; *Pyrenophora teres*; *Pyrenophora graminea*; *Rhynchosporium secalis*; pathogens; hosts; genotype environment interaction; Cyprus.

الملخص

يعتبر الشعير (*Hordeum vulgare* L. subsp. *vulgare*) أهم المحاصيل التي تزرع بعلاً في قبرص. وتنتشر الأمراض التي تصيب الأوراق على نطاق واسع، إلا أن أهميتها الاقتصادية لم تقيم بعد. وفي الفترة الأخيرة، تم الشروع في إجراء دراسات حول اختبار التفاعل بين العائلX العامل الممرض X البيئة. ويتم التركيز على التربية والمعاملات الزراعية لمكافحة أمراض الشعير.

Production trends

Cyprus has a semi-arid climate. Rainfall varies between 200 and 500 mm per year, winters are mild with monthly average night and day temperatures of 5–7°C and 15–20°C, respectively; summers are hot with mean monthly maximum temperatures 35–38°C. The two main cereal crops, barley and wheat, have been cultivated in Cyprus for millenia. Both crops are important in the agricultural economy of the country, but the most important is winter-sown spring barley. The main use of barley is for livestock feed, either as hay or grain.

In 1964, Cyprus initiated determined efforts to increase cereal production with a view to reducing imports. This task, under the auspices of the Agricultural Research Institute (ARI) of Cyprus, aimed to increase both crop area and yield. The area under barley has expanded to all districts of the island and also into marginal lands. However, imports of barley have increased despite new high-yielding cultivars being released by ARI. Barley consumption is considerably higher than production, which satisfies 10–25% of the total annual consumption depending upon the growing season (Table 1). About US$ 24–28 million is spent annually on barley imports (Cyprus Grain Commission 1990).

Table 1. Mean values of area under barley grown, grain production, consumption and imports.

Area	55,000 ha
Annual production	103,000 tonnes
Consumption	378,000 tonnes
Annual imports	275,000 tonnes
Values of imports	US$ 24–28 million

Diseases

Barley is attacked by several pathogens, some highly destructive, others irregular in occurrence. Changed farming systems, including monocultures of new improved varieties, continuous barley cropping and increased fertilization, combine with favorable weather conditions (moisture and temperature) to determine pathogen development.

In Cyprus, there is little information on the relationship between host and pathogen. There are reports that foliar diseases are widespread (Hadjichristodoulou 1981; Nattrass 1937; Parisinos 1956; Zyngas 1973), but their effects (yield losses) have not been studied systematically. The most destructive foliar diseases of barley in Cyprus are: *Rhynchosporium secalis* (Oud.) J.J.Davis (scald); *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.) (net blotch); *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. (= *Bipolaris sorokiniana* (Sacc.) Shoem.) (Syn. *Helminthosporium sativum* Pammel, King & Bakke) (spot blotch); *Pyrenophora graminea* S.Ito & Kuribay. (= *Drechslera graminea* (Rab.) Shoem.) (Syn. *Helminthosporuim gramineum* Rabh.) (barley stripe), and *Erysiphe graminis* DC. ex Mérat f.sp. *tritici* E.Marchal (= *Oidium monilioides* Desm.) (powdery mildew). Leaf blight caused by *Pseudomonas syringae* van Hall pv. *syringae* and *Xanthomonas campestris* f.sp. *hordei* are very rare and of negligible importance. Seedling and head blights caused by *Fusarium* sp. have also been observed, but their importance has not been evaluated.

General status of barley diseases

In 1992, the incidence of foliar diseases was quite high (25–35%), while severity was low to moderate (10–20%), presumably due to the dry January and high temperatures after anthesis. Both factors would have inhibited pathogen multiplication and disease progress.

Powdery mildew was the most prevalent disease in Athalassa and Dromolaxia, but was negligible in Laxia and Akhera. The most advanced cross, Mari/Athenais*2-02-CYB180-2A-2A-2A-OA, and its two selected sister lines, SEL-A and SEL-B, had the greatest infection with powdery mildew (23, 20 and 10%, respectively) and Kantara had the lowest (5%); Athenais was intermediate (10%).

Net blotch affected an average of 5 and 15% of the seventh leaf of cultivars Athenais and Kantara, respectively. Scald was negligible on all advanced cultivars. The coefficient of infection (CI) of leaf rust was very low and of negligible importance.

Research status

Diseases can be controlled by fungicides and by growing resistant host plants. Fungicides are costly, harm the environment and pathogens may develop resistance to them. In Cyprus, fungicide use is not economical. Thus, disease control is largely based on breeding and cultural practices.

Comprehensive studies are underway to estimate the economic importance of diseases, to examine the interaction among host, pathogen and environment, to determine the effect of nitrogen on disease development, and to evaluate the value of barley mixtures.

Preliminary results suggest an average 10% yield loss from net blotch and powdery mildew. Yield components, such as volume weight and 1000-grain weight, increased in sprayed treatments by 4.5 and 12.2%, respectively (Table 2). In dryland conditions, yield losses from diseases are not consistent, but fluctuate with environmental conditions. Continuous barley cropping and the excessive use of nitrogen fertilizer has increased the susceptibility of barley to some pathogens such as *Pyrenophora teres*, *Rhynchosporium secalis* and *Erysiphe graminis*.

We have examined the use of mixtures as an alternative for barley disease control (Jeger et al. 1981; Wolfe et al. 1981). Mixtures are acceptable when the produce is used mainly for livestock feed. Preliminary results indicate that the percentage leaf damage was reduced for net blotch and powdery mildew in some mixtures. The level of disease was affected by the genotypes used in duocultures and usually yielded above the average of their components grown in pure stands (by 2–8%) (Table 3).

Kantara + Mari/Aths*2-02-CYB180-2A-2A-2A-OA-SEL-B was the best duoculture; it outyielded its components by 2.8 and 8% (Table 3). Infection frequency of powdery mildew was 15.8% lower than that on Mari/Aths...SEL-B, but

Table 2. Mean values of yield, volume weight, 1000-grain weight, net blotch and powdery mildew over three cultivars and their duocultures when sprayed or not sprayed with fungicide.

	Grain yield (kg/ha)	Volume weight (g)	1000-grain weight (g)	Net blotch†	Powdery mildew†
Control	4793 b	56.8 b	37.8 b	8.6 a	9.1 a
Fungicide	5276 a	59.3 a	42.4 a	1.5 b	1.8 b
SE (±)	153	0.47	1.05	0.23	0.23
(%) change	+10	+4.4	+12.2	-82.5	-80.2

† Angular values from the three upper leaves.

7.6% higher than that on Kantara. The opposite situation occurred for net blotch: infection frequency was 43.8% less on duoculture compared with that on pure Kantara and 13.3% greater than that on pure Mari/Aths...SEL-B.

Table 3. Yield and disease incidence of three barley cultivars and their duocultures.

Genotype(s)	Grain yield (kg/ha)	Powdery mildew†	Net blotch†
Pure stand			
K	8085	18.83	8.60
A	7733	16.21	5.71
M/A	8495	24.05	4.26
Mixture			
K × A	8266	19.07	3.16
K × M/A	8733	20.26	4.83
K × M/A	8190	20.70	3.47

K= Kantara; A= Athenais; M/A= Mari/Aths*2-02-CYB180-2A-2A-2A-OA-SEL-B.
† Angular values.

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Barley Leaf Blights Research in Morocco

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Abstract

Disease surveys carried out in Morocco between 1985 and 1990 showed that net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) is the major foliar disease on barley (*Hordeum vulgare* L. subsp. *vulgare*). Barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) and scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) were present but at lower frequencies and severities. Yield losses due to net blotch were estimated at up to 30%. Studies on host–pathogen interaction showed high variability of *P. teres* isolates in Morocco. While most of the local varieties were susceptible to the disease, several introduced cultivars showed good resistance. There is little information on barley stripe and scald in Morocco.

Key words: *Hordeum vulgare*; barley; disease resistance; *Pyrenophora teres*; *Pyrenophora graminea*; *Rhynchosporium secalis*; Morocco.

الأبحاث حول أمراض لفحة الأوراق على الشعير في المغرب

الملخص

أظهر حصر للأمراض أجري في المغرب بين 1985 و1990، أن التبقع الشبكي (*Pyrenophora teres* Drechs.[=*Drechslera teres* (Sacc.) Shoem.]) و المرض الورقي الرئيسي على الشعير (*Hordeum vulgare* L. subsp. *vulgare*). كما شوهدت إصابات بتخطط الشعير (*Pyrenophora graminea* S.Ito & Kuribay [=*Drechslera graminea* (Rab.) Shoem.]) والسفحة (*Rhynchosporium secalis* (Oud.) J.J. Davis) ولكن على نحو أدنى تواتراً وشدة. ويصل الفاقد في الغلة الناجم عن التبقع الشبكي إلى 30٪ وقد بينت الدراسات على التفاعل بين العائل – العامل الممرض تنوعاً كبيراً في عزلات *P. teres* في المغرب. ففي حين كانت معظم الأصناف المحلية حساسة للمرض، أظهرت عدة أصناف مدخلة مقاومة جيدة. وماتزال المعلومات عن مرضيّ تخطط الشعير والسفحة قليلة في المغرب.

Key words: *Hordeum vulgare*; barley; disease resistance; *Pyrenophora teres*; *Pyrenophora graminea*; *Rhynchosporium secalis*; Morocco.

Introduction

Barley is a major cereal in Morocco. It occupies more than 2 million hectares annually and the national average yield is about 1000 kg/ha. There is a large gap between attainable yield and that actually achieved at the farm level. The most obvious causes of this are drought and disease.

In the early 1980s, the primary concern of Moroccan scientists was to increase grain yield and yield stability. Breeding for foliar disease resistance, except for powdery mildew, was neglected. More recently, in examining and adjusting breeding goals, priority has been given to the identification of sources of resistance, characterization and distribution of the major pathogens, and incorporation of resistance genes into adapted varieties.

Each year, more than 60% of the crosses made are aimed at improving disease resistance levels, and thousands of barley lines are tested and screened in the glasshouse and field for their resistance to the prevalent pathogens.

Disease surveillance

Since 1985, surveys have been organized each year to determine the prevalence of leaf diseases attacking cereals. In 1985 to 1990, net blotch was present in all barley fields examined and disease severity was high (Tables 1 and 2). Scald was found occasionally in barley fields and did not appear every year. Barley stripe, although present every year, declined in importance. This may be due to increased use of fungicide-treated seeds by farmers.

Survey results of a typical year (Lyamani 1989), with percentage of fields infected and severity frequencies of different leaf diseases in north and south Morocco are illustrated in Figures 1, 2 and 3. Net blotch is found in all fields in the south and severity is higher than 40% in 40% of fields (Fig. 1). This disease is also prevalent in the north, where it is found in 90% of fields (Fig. 2), 38% of which had a severity higher than 40%. Scald and barley stripe were present mostly in the north with low severities.

Yield losses

Little information is available on yield losses from barley leaf blights (Table 3). Although net blotch has been known for many years as the most significant leaf disease on barley in all areas of Morocco, few data are available on actual losses attributable to this disease, but losses as high as 30% have been reported in susceptible cultivars (Burleigh et al. 1986). Yield losses due to scald and barley stripe have not been thoroughly evaluated.

Table 1. Occurrence of barley leaf diseases (% infected fields) in Morocco, 1985–90.

Disease	1985/86	1986/87	1987/88	1988/89	1989/90
Net blotch	100	100	100	98	100
Scald	35	–	29	20	6
Barley stripe	65	60	29	24	2
Powdery mildew†	74	15	–	13	29

† *Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal (= *Oidium monilioides* Desm.).

Table 2. Barley leaf disease severities (% infected fields) in Morocco, 1985–90.

Disease	1985/86		1986/87		1987/88		1988/89		1989/90	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Net blotch	Tr	75	5	100	10	100	34	90	60	90
Scald	Tr	25	–	–	Tr	80	4	30	30	50
Barley stripe	Tr	100†	Tr	100	Tr	50	2	10	Tr	Tr
Powdery mildew	Tr	100	Tr	Tr	–	–	18	40	Tr	Tr

Tr = trace.
† Infected plants (%).

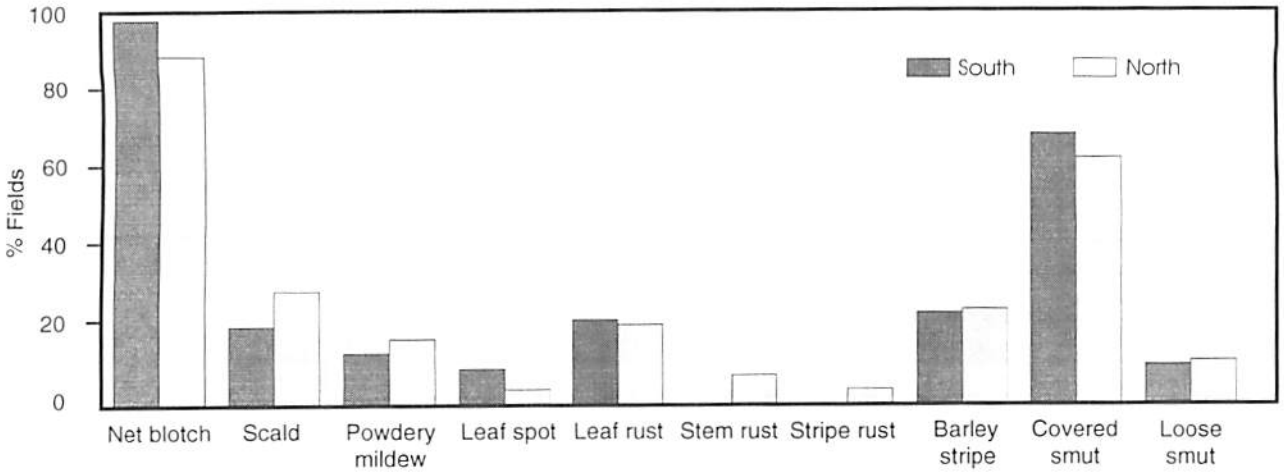

Figure 1. Frequencies of barley leaf diseases in north and south Morocco, 1989.

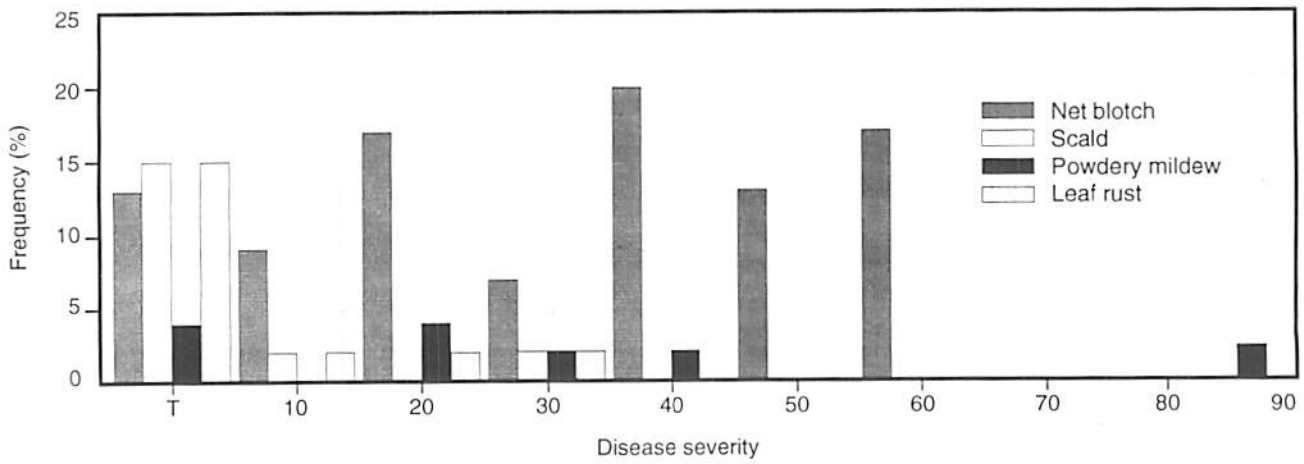

Figure 2. Severity frequencies of barley leaf diseases in south Morocco, 1989.

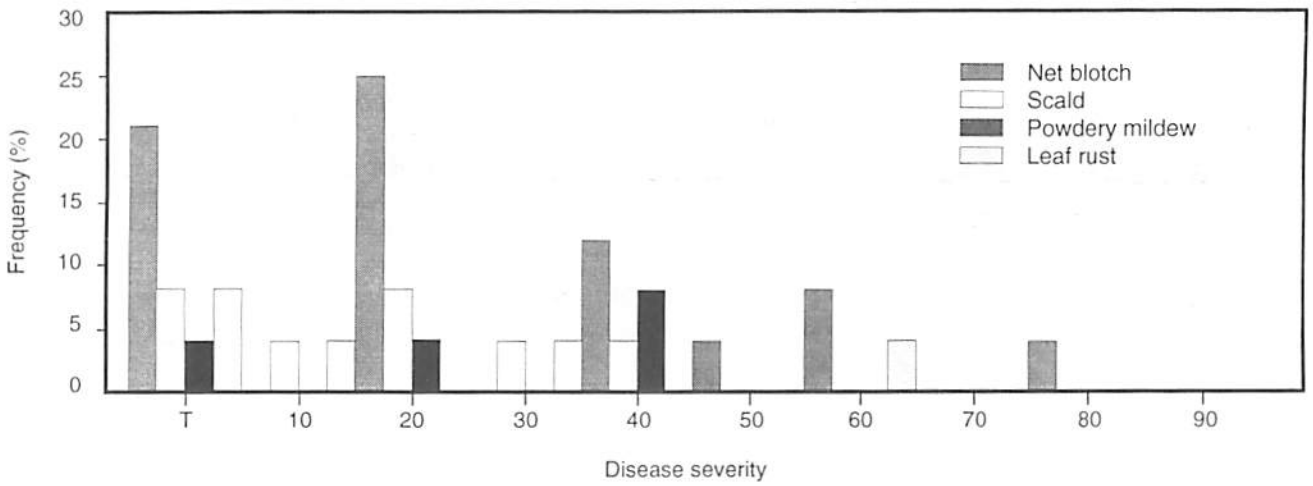

Figure 3. Severity frequencies of barley leaf diseases in north Morocco, 1989.

Table 3. Estimations of barley grain yield losses caused by the prevalent diseases in Morocco.

Disease/pest	Losses (%)	Reference
Net blotch	30	Burleigh et al. (1986)
Powdery mildew	26	Mergoum (1983)
BYDV	16–23	Amri et al. (1991)
Hessian fly†	24	Lhaloui et al. (1988)

† *Mayetiola destructor* Say.

Net blotch

Pathogen variabiltiy

Net blotch occurs primarily as the net form of *P. teres* f.sp. *teres*. The spot form was reported the first time in Morocco by Bockelman et al. (1983) and is less common.

Variation in virulence among isolates of *P. teres* has been studied by a number of workers. Hadri and Ezzahiri (1988) evaluated 10 barley cultivars for their reaction to four isolates of *P. teres* f.sp. *maculata* Smedegaard-Petersen and 12 isolates of f.sp. *teres* (Table 4). They found that isolates of f.sp *teres* had higher mean severity than those of f.sp. *maculata* (Table 5). The leaf area infected by f.sp. *teres* varied from 1 to 90%, while infection by f.sp. *maculata* did not exceed 30%. The most virulent isolates of f.sp. *teres* were collected from Boulaouane and Ben Ahmed sites. ACSAD 176 and Asni had high resistance to all 16 isolates (Table 6).

Cheddad and Lyamani (1992) tested 42 isolates on Arig 8, of which 23 were non-virulent. The same authors tested 10 isolates on 71 varieties and found 2 isolates avirulent, 4 moderately virulent, and 4 highly virulent. They also found that *P. teres* collected from plants with net-type symptoms could produce either net- or spot-type symptoms, and vice versa. These findings await confirmation.

Several varieties and lines reported as highly resistant or resistant were tested with six isolates (4 from Morocco, 1 from Minnesota, 1 from Montana) in the glasshouse. The same group of varieties and lines was tested under natural infection in the field at two different locations in Minnesota. The results (Table 7) show that Minnesota and Montana isolates had higher mean virulence than the Moroccan isolates used. Barley lines NB D112 and Heartland showed high resistance to the 6 isolates in the glasshouse and in the field.

Table 4. Seedling reaction of 10 barley cultivars to 16 isolates of *Pyrenophora teres* f.sp. *teres* and f.sp. *maculata*.

Cutivar	Highly resistant	Moderately resistant	Intermediately resistant	Moderately susceptible	Susceptible
ER/APM		8,*2*,*4*	*1*	11,10,9,15,*3*,16,12,14	7,5,6,13
Br. Maroc		8,*1*,*4*	*2*	11,10,9,15,16,12,14,*3*	7,5,6,13
Tamellalet	12,13	9,*3*,14,*1*	*2*,*4*	7,11,6,10,15	5,8
Z-28		5,6,10,9,214,13,*4*	*1*	7,8,11,16,12	*3*
Tissa	12,14	5,6,10,*3*,*2*,16,*1*,13	*4*	7,8,11,9,15	
NK 1272		7,8,6,9,*3*,*2*,12,*1*,*4*		5,11,10,15,16,14,13	
Arig 8	10,9	8,11,6,15,14,*1*,13,*4*	*2*	5,*3*,16	7,12
ACSAD 60	12,14,13	7,8,11,6,9,15,*3*,*2*,16,*1*	*4*	5,10	
Asni	7,9,12	5,6,15,*2*,*1*,14,3,*4*	*3*	8,11,10,16	
ACSAD 176	8,10,9,*2*,16,12,14,13,*4*,	5,11,6,15,*3*,*1*		7	

Italicized numbers refer to *P. teres* f.sp *maculata* isolates.
Source: Hadri and Ezzahiri (1988).

Table 5. Mean severity of *Pyrenophora teres* on 10 barley varieties.

Cultivar	Severity mean†
ER/APM	32.67 a
Br. Maroc	27.69 b
Tamellalet	27.39 b
Z-28	24.69 c
Tissa	24.04 cd
NK 1272	23.45 cd
Arig 8	23.34 cd
ACSAD 60	23.09 d
Asni	19.86 e
ACSAD 176	17.13 f

† Arc sin % of leaf area infected; 16 *P. teres* isolates listed in Table 6 were used.
Source: Hadri and Ezzahiri (1988).

Table 6. Mean severity of isolates of *Phrenophora teres* over 16 barley varieties.

Isolate No.	Origin	Severity mean†
7	Boulaouane	35.15 a
5	Ben Ahmed	35.04 a
8	Tassaout	31.54 b
11	Oulad Abbou	27.76 bc
6	Marrakech	29.29 cd
10	Berrechid	27.26 de
9	Settat	26.65 e
15	Ben Ahmed	25.68 e
3	Merchouch	22.30 f
2	Tanger	20.91 fg
16	Meknes	20.20 fg
12	Yoyssoufia	19.80 g
14	Jmaa Shaim	18.70 gh
1	Taroudant	17.03 hi
13	Khemisset	15.90 ij
4	Berrechid	14.14 j

† Arc sin % of leaf area infected; the 10 barley varieties listed in Table 5 were used; entries followed by the same letter are not significantly different at the 5% probability level.
Source: Hadri and Ezzahiri (1988).

Ben Ali and Lyamani (1992) studied growth of *P. teres* on V8 medium, and toxin production and disease severity on cultivar Arig 8 in the glasshouse. They used 96 *P. teres* isolates collected from different regions in Morocco. The *P. teres* populations were highly variable. They isolated and purified three toxins: pyroline A, pyroline B and pyronolide A. A new toxin was also observed and awaits identification.

Germplasm screening

Caddel and Wilcoxson (1975) tested 143 US barley cultivars and lines in the field in Morocco, and found 19 resistant to net blotch. A few cultivars were also resistant to other pathogens.

Thirty lines, reported resistant at other locations, were subjected to natural infection at Merchouch experimental station; 16 were resistant to highly resistant. Of 6064 barley varieties and lines screened from the world collection, 450 lines had a good level of resistance (scored less than 3 on a scale of 1 to 9) in the first year. However, in the second year, only 9 of these 450 lines showed satisfactory resistance.

Table 7. Seedling and field reactions to *Pyrenophora teres* of 39 genotypes of barley.

Genotype	Seedling reaction†						Field reaction‡	
	SL	35N	69N	SK	MN	MO	Cr	St
CI 2333	R	MR	-	MS	R	R	MR	R
CI 2549	R	MS	MR	S	MR	S	R	R
CI 4976	-	R	MS	R	R	R	MR	R
CI 6688	R	MS	MR	MR	R	R	R	R
CI 9440	R	MR	MR	R	R	R	R	R
CI 9699	R	R	MR	R	R	R	R	R
CI 9820	R	R	R	R	R	R	MR	R
CI 9881	R	R	R	R	MR	MR	MR	MR
CI 10379	R	MR	MR	R	R	R	MR	MR
CI 10877	R	MS	MS	S	MS	S	MS	S
CI 11638	R	R	R	MS	S	MR	MR	R
CI 12034	R	S	MS	MS	S	MS	MR	MR
CI 12674	R	MR	R	R	R	R	MS	R
Minn 7	R	S	MS	S	MS	MR	MR	MR
NDB 112	-	R	R	R	R	R	R	R
Moore	S	S	MS	S	MS	S	MS	MS
CI 10648	R	MR	R	R	S	S	R	S
CI 4118	R	MR	R	MR	R	S	MS	S
Triumph	R	R	R	R	R	S	MR	MR
Anoidium	R	S	MR	S	R	MR	R	MR
CI 1251	R	R	R	R	S	MR	MR	MR
Morex	MR	MR	R	R	S	S	MR	MS
Robust	MR	MR	MR	MR	MS	MS	R	MR
Excel	R	R	R	MR	MS	MS	R	MS
Heartland	R	R	-	R	R	R	MR	R
M 85-420	MR	R	MR	MR	MR	MR	R	R
M 85-421	R	R	R	R	MS	R	MR	R
M 85-422	MS	MS	MR	MR	-	-	R	MR
M 85-424	MR	MR	MR	R	MS	MS	R	MR
Arig 8	R	R	MR	MR	MR	R	MS	MS
ACSAD 60	R	MR	MR	R	S	R	MR	MS
ACSAD 176	R	MR	MR	S	MS	R	-	MR
ASNI	-	R	-	R	MS	MR	MS	S
Tissa	-	MR	R	R	MR	MS	MR	S
Br. Maroc	R	MS	R	S	S	R	R	S
ER/APM	R	MS	MR	S	S	MS	MR	MR
Harmal	MR	MR	R	R	S	R	-	MR
Tamelalt	R	S	MR	S	R	R	-	MR
Rabat 071	-	S	S	S	R	R	MR	-

† Isolates from SL = Sidi Laydi; SK = Sidi Kacem; MN = Minnesota; MO = Montana.
‡ Field reaction at Cr = Crookston; St = Stephen.

Barley stripe

The inheritance and genetics of resistance to barley stripe was studied using five cultivars that were adapted, but different in their reaction to stripe (Boulif and Wilcoxson 1988). The cultivars studied were: Atlas 68 and Merzaga 077 (susceptible to stripe), Arig 8 (moderately resistant), and Minnesota 23 and CI 9737 of American and Ethiopian origin, respectively (resistant to stripe) (Table 8). Using one local virulent isolate, they found that stripe-resistance in Minnesota 23 was conferred by a single dominant gene and that resistance in CI 9737 was conferred by two genes when crossed to Merzaga 077. In cross CI 9737 × Atlas 68, resistance was controlled by recessive genes, but the number could not be determined. Resistance in Arig 8 was heritable but its genetic control was not elucidated because of the intermediate level of resistance in Arig 8.

Of 470 barley cultivars from ICARDA, tested using a local isolate of *P. graminea*, 48 were resistant with less than 5% of plants infected; 28 of these had no infection.

Scald

Studies on scald are very limited in Morocco. During the 1980s, only one epidemic occurred (in 1986). All lines grown that year at Merchouch (total of 18,000) were highly susceptible.

Conclusions

In Morocco, net blotch is the major barley leaf blight. Barley stripe is prevalent but it is declining in importance. Scald is observed only in some years and is localized.

In terms of breeding, little or no progress has been made in improving resistance to *P. teres*. The current promising lines are as susceptible as the landraces or the cultivars released in 1976 (Table 9). However, a large number of genotypes identified possess sufficient resistance to be of potential value in the barley breeding program. In contrast, no source of resistance is available so far for scald.

Table 8. Percentage of stripe-infected plants and classification of disease reaction of barley genotypes used as parents.

	Atlas 68	Merzaga 077	Arig 8	CI 9737	Minn 23
Artificial inoculation (% inf.)	64–72	40–62	19–33	0	0–5
Natural infection (% inf.)	9–40	5–20	11–5	0	0
Reaction	S	S	MS	R	R

Source: Boulif and Wilcoxson (1988).

Table 9. Grain yield, total biological yield, phenological agronomic characteristics, and disease reaction of different groups of barley cultivars, 1988–89.

Genotype group	Grain yield (Qc/ha)	Biol. yield (Qx/ha)	Diseases†				Lodging (0–9)	Plant height (cm)
			PM (0–9)	NB (0–9)	Sc (0–9)	BYDV		
Landraces (5)	26.6	116.1	9	9	6	S	9	115
Cvs released 1976 (2)	29.7	116.7	4	7	6	S	5	105
Cvs released 1983 (6)	30.5	102.6	3	8	6	S	3	92
Cvs released 1988 (2)	33.7	96.5	1	7	5	S	1	90
Promising lines (6)	33.4	113.9	5	7	5	S	3	95

† PM = powdering mildew; NB = net blotch; Sc = Scald; BYDV = Barley Yellow Dwarf Virus.
Source: Amri et al. (1991).

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Barley Leaf Blights in Egypt with Emphasis on Net Blotch

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Abstract

In Egypt, barley (*Hordeum vulgare* L. subsp. *vulgare*) is grown under rain-fed conditions in the North West Coast (NWC) and Sinai, and a little is grown irrigated in the Nile Valley. Disease surveys in 1988–92 showed that net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem. (Syn. *Helminthosporium teres* Sacc.)]) is an important problem in the NWC. In the Delta region, this disease decreased in severity to the south. Up to 16 pathological races of *P. teres* have been identified in Egypt. A strong correlation has been recorded between disease severity (up to 60%) and grain yield per head and 1000-kernel weight. At infection severities above 60%, there was a rapid increase in yield loss. The best chemical control agent identified for net blotch is propiconazole. Barley leaf stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem. (Syn. *Helminthosporuim gramineum* Rabh.)]) causes considerable damage in the northern provinces of the Nile Delta; the best chemical control agent identified to date is

أمراض لفحة الأوراق على الشعير في مصر مع التركيز على التبقع الشبكي

الملخص

يزرع الشعير(*Hordeum vulgare* L. subsp. *vulgare*) في مصر تحت ظروف بعلية في الساحل الشمالي الغربي (NWC) وسيناء، في حين يزرع القليل منه مروياً في وادي النيل. وقد أوضحت دراسات حصرية للأمراض نفذت خلال 1988-1992. أن التبقع الشبكي (*Pyrenophora teres* Drechs. [=*Drechslera teres* (Sacc.) Shoem. (Syn. *Helminthosporium teres* Sacc.)]) هو مشكلة هامة في NWS. وفي منطقة الدلتا، تضعف شدة هذا المرض باتجاه الجنوب. وقد تم التعرف على مايصل مجموعه إلى 16سلالة مرضية من *P. teres* في مصر، وسجل ارتباط قوي بين شدة المرض (تصل إلى 60٪) والغلة الحبية في كل سنبلة ووزن الألف حبة. وعندما تصل شدة الإصابة إلى مايزيد على 60٪، يتزايد فاقد الغلة على نحو سريع. وإن أفضل مبيد كيميائي تم التعرف عليه لمكافحة التبقع الشبكي، هو البروبيكونازول. كما يسبب مرض تخطط أوراق الشعير (*Pyrenophora graminea* S.Ito & Kuribay. [=*Drechslera graminea* (Rab.) Shoem. (Syn. *Helminthosporuim gramineum* Rabh.)]) أضراراً هامة في المحافظات الشمالية من دلتا النيل، علماً أن أفضل

prochloraz. Scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) was first recorded in Egypt in 1991/92, and is restricted to the western part of the NWC.

Key words: *Hordeum vulgare*; barley; *Pyrenophora teres*; *Pyrenophora graminea*; *Rhynchosporium secalis*; prochloraz; chemical control; disease control; Egypt.

مبيد كيميائي لمكافحة هذا المرض حتى الآن، هو البروكلوراز. أما السفحة (*Rhynchosporium secalis* (Oud.) J.J. Davis)، فقد سجلت لأول مرة في مصر في 92/1991. وهي محصورة في الجزء الغربي من NWC.

Introduction

In Egypt, most barley is grown in the North West Coast (NWC) and Sinai under rain-fed conditions. Limited areas of barley are grown under irrigation in the Nile Valley.

Barley is attacked by several leaf blights, mainly *Pyrnophora teres*, the causal organism of net blotch, *P. graminea*, causing stripe disease, and *Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast., causing spot blotch. Barley is also attacked by *Rhynchosporium secalis* (scald) in Egypt.

Net blotch

Both net- and spot-type symptoms have been noted on barley. In Egypt, net-like symptoms are common, while spot-type symptoms were recorded for the first time in 1990, on 3% of isolates tested (El-Nashar 1990).

Disease survey

Under the umbrella of the Nile Valley Project of the International Center for Agricultural Research in the Dry Areas, barley disease surveys have been carried out annually in the NWC. Between 1988 and 1992, net blotch was one of the major diseases in the NWC and maximum infection was recorded in 1989/90 (Ghobrial et al. 1990; Rizk 1991; Noaman et al. 1992). In the Delta Region (on irrigated barley), net blotch is widespread and the highest level of infection was at Sakha, with severity decreasing gradually towards the south (Abdel-Hak et al. 1981).

Physiological specialization of Pyrenophora teres

The existence of physiological races of *P. teres* was first studied by Pon (1949), who reports that isolates of *P. teres* differed sharply in their pathogenicity on certain barley varieties. McDonald and Buchannon (1964), Gray (1967), and Khan and Boyd (1969) identified races of *P. teres* using different sets of barley genotypes as differentials. In Egypt, racial identification of *P. teres* started in 1974 when 60 varieties were selected from the barley world collection on the basis of their different reactions to this pathogen as well as their adaptation to Egyptian environments. Six entries exhibited clear differential reactions and are used differentiate *P. teres* in Egypt (El-Fahl et al. 1979): Nepal (C.I. 475), Gold (C.I. 1145), Bolivia (C.I. 365), Atlas (C.I. 4118), Lechtaler (C.I. 6488) and Giza 117 (C.I. 11190). Sixteen races were identified during 1974–76. El-Nashar (1983, 1990) identified 4 and 10 physiologic races, respectively, using the same differentials.

Loss assessment

Losses from net blotch have been estimated using various methods. In the USA, yield loss from net blotch was estimated to be as high as 15% in the early 1920s. In Canada, McDonald and Buchannon (1964) compared the yield of a susceptible variety with that of a resistant one; they suggest yield losses of 20%. Shipton (1966) compared the yields and grain quality from experimental plots regularly sprayed with fungicide; he recorded a yield reduction of 17% due to net blotch. Richardson et al. (1975) used the single-tiller method based on random samples taken from numerous fields. In Egypt, El-Nashar (1990) found a gradial reduction in yield/head and 1000-kernel weight of three cultivars correlated with net blotch severity up to 60%. With higher net blotch severity losses increased sharply. The number of kernels/head was not affected by disease severity; this indicates that the main effect of net blotch of barley is in reducing grain weight.

Chemical control

Most Egyptian barley cultivars are susceptible to net blotch, therefore chemical fungicides may help to control the disease. Six fungicides were evaluated in the greenhouse and under field conditions. Tilt (propiconazole) gave satisfactory control of net blotch, followed in efficacy by Bayleton (triadimefon) and Kitazin (iprobenfos) (Abdel-Hak et al. 1981; El-Nashar et al. 1990).

Resistance to net blotch

Annual testing of commercial varieties, promising high-yielding lines and exotic barley lines is done at both seedling and adult stages. High-yielding entries with broad-based resistance are selected for use in the breeding program by the

Cereal Diseases Division of the Plant Pathology Institute, and the Barley Breeding Section of the Field Crops Institute.

Barley leaf stripe

Barley leaf stripe is a problem in North Africa, the Middle East, northwest Europe and southwest USA (Metz and Scharen 1979). In Egypt, the disease was recorded for the first time in 1922 by Briton Johns. Considerable damage occurs on some Egyptian cultivars in the northern provinces of the Nile Delta (Abdel-Hak and Ghobrial 1977).

El-Ghamry et al. (1991) evaluated 150 barley genotypes for their resistance to leaf stripe and selected 44 resistant genotypes. Also, eight fungicides were tested as seed dressings to control the disease under field conditions. Prelude (prochloraz) was best, followed by Vitavax 200 FF (mostly carboxin), Vincit F (flutriafol + thiabendazole) and Raxil (tebuconazole).

Scald

Scald of barley occurs in many parts of the world particularly in cool areas. In Egypt, Rizk et al. (in press) recorded the disease for the first time in the NWC area during 1991/92. The disease was restricted to the western parts of the NWC.

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Scald, a New Barley Disease in Egypt

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Abstract

Surveys of barley scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) on the North West Coast of Egypt revealed that the disease was restricted to the western areas. The highest incidence and severity was recorded at El-Mathani. This is the first record of scald in Egypt. Disease resistance was studied on a total of 378 barley genotypes at El-Mathani under natural inoculation. Of these, 140 were resistant to scald. Some genotypes combined both high yield potential and good resistance.

Key words: *Hordeum vulgare*; barley; disease resistance; selection; genotypes; *Rhynchosporium secalis*; yields; Egypt.

Introduction

Scald of barley (*Hordeum vulgare* L. subsp. *vulgare*), caused by *Rhynchosporium secalis*, is a major disease in many regions, particularly in the cooler and semi-humid areas (Ali 1975; Shipton et al. 1974). The disease causes considerable yield losses in Ethiopia (Gebre 1981), Portugal (Barradas 1981), Afghanistan and Kenya (Mamluk 1981). It also exists in Turkey, Syria (Bayaa et al. 1978) and most barley-producing areas of the world including North Africa.

The main objectives of this study were to identify the scale of the scald problem in Egypt through quantitative and qualitative field surveys and to select resistant barley genotypes which can be used as sources of resistance in breeding programs.

Material and Methods

Surveys of growers' fields for the distribution and severity of scald were carried out in late March and early April along the North West Coast (NWC) and in North Sinai. The sampling unit was 100 plants per field. The plants were taken from 10 different spots selected at random. Some samples were brought into the laboratory for pathogen isolation and identification.

السفحة، مرض جديد على الشعير في مصر

الملخص

كشفت الدراسات الحصرية على سفحة الشعير (*Rhynchosporium secalis* (Oud.) J.J. Davis) التي أجريت في الساحل الشمالي الغربي من مصر، أن الإصابة بهذا المرض محصورة بالمناطق الغربية، وسجلت أعلى الإصابات وأكثرها شدة في الماثاني علماً أنها الإفادة الأولى عن مرض السفحة في مصر. وقد دُرست مقاومة المرض على ما مجموعه 378 طرازاً وراثياً من الشعير في الماثاني تحت ظروف التلقيح الطبيعي، فتبين أن 140 طرازاً وراثياً من تلك الطرز كانت مقاومة للسفحة، كما تمتعت بعضها بكفاءة إنتاجية عالية ومقاومة جيدة معاً.

Three sets of barley genotypes were tested for resistance to scald under field conditions at El-Mathani in NWC. These were KLDN–1991/92 (200 lines); BON-L–1991/92 (68 lines); and, a set of 87 barley genotypes including local and exotic material.

Each entry was planted in two rows, 3.5 m long and 30 cm apart. Checks of local and commercial varieties were included throughout the nurseries and as borders. Disease assessment was carried out at growth stage 10.5 on Feek's scale (Large 1954). The disease score was based on the intensity of the disease on the foliar parts using a scale of 0–9 (Saari and Prescott 1975).

Results and Discussion

Although the occurrence of scald in Egypt was not published earlier, we saw a few plants infected with scald during the previous three seasons. Severity of the disease was very low and no attention was given to it.

During the 1992 season, the climatic conditions (temperature, relative humidity and rainfall) were suitable for scald development, although the disease was restricted to the western part of the NWC, i.e. Wadi El-Washk, El-Mathani, El-Negila, El-Garara and Sidi-Barani. The highest incidence and severity was recorded at El-Garara (Table 1).

Scald was recorded on 376 barley genotypes at El-Mathani under natural inoculation. The results obtained may be summarized as follows: in the KLDN–1991/92, 74 barley genotypes were resistant; in the BON-L–1991/92, 28 entries were resistant; and in the third set, 38 genotypes were resistant.

Table 1. Survey of scald in Egypt, 1992.

Location	No. infected plants	Severity (%)
Nubaria	0	–
El-Dabaa	0	–
Atnouh	10	3
El-Kasr	0	–
Wadi-El-Wasbek	10	2.5
El-Mathani	70	25
El-Negila	50	15
El-Garara	80	35
Sidi-Barani	5	20
El-Arish†	0	–
Rafah†	0	–

† El-Arish and Rafah, locations in North Sinai.

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Barley Disease Research in Germany

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Abstract

Barley (*Hordeum vulgare* L. subsp. *vulgare*) is the second most important cereal in Germany, after wheat (*Triticum* spp.). Winter and spring barleys occupied some 2.4 million ha in 1992, with an average yield of 5 t/ha. The important leaf blights affecting barley in Germany are (in decreasing order of importance): powdery mildew (*Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal [= *Oidium monilioides* Desm.]), leaf rust (*Puccinia hordei* Otth), net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]), scald (*Rhynchosporium secalis* (Oud.) J.J.Davis), stripe rust (*Puccinia striiformis* West. f.sp. *hordei*), and spot blotch (*Cochliobolus sativus* (Ito &

أبحاث أمراض الشعير في ألمانيا

الملخص

يأتي الشعير (*Hordeum vulgare* L. subsp. *vulgare*) في المرتبة الثانية بين محاصيل الحبوب في ألمانيا، بعد القمح (*Triticum* spp.). وقد شغل الشعير الشتوي والربيعي مساحة قدرها 2.4 مليون هكتار تقريباً في عام 1992 وبمتوسط غلة 5 طن/هـ، وإن أمراض لفحة الأوراق التي تصيب الشعير في ألمانيا (مرتبة بالتتالي حسب الأهمية) هي: البياض الدقيقي (*Erysiphe graminis* DC. ex Merat f.sp. *hordei* Em.Marchal [=*Oidium monilioides* Desm.])، صدأ الأوراق (*Puccinia hordei* Otth)، التبقع الشبكي (*Pyrenophora teres* Drechs. [=*Drechslera teres* (Sacc.) Shoem.])، السفحة (*Rhynchosporium secalis* (Oud.) J.J. Davis)، الصدأ المخطط (*Puccinia striiformis* West. f.sp. *hordei*)، والتبقع الهلمنثوسبوري (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [=*Bipolaris sorokiniana* (Sacc.) Shoem.]) وأصبح مرض التبقع الشبكي مشكلة في ألمانيا الغربية

Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem.]). Net blotch became a problem in West Germany in the 1970s, and in East Germany in the 1980s. The delay in occurrence in the east is presumed to be related to the later introduction there of fungicidal treatment to control powdery mildew. Both net blotch and scald severity are strongly influenced by the weather. Resistance breeding is still in its infancy in Germany, but work is underway to identify isolates of the net blotch and scald pathogens, and to compare the resistance among barley genotypes.

Key words: *Hordeum vulgare*; barley; plant breeding; disease resistance; *Pyrenophora teres*; *Pyrenophora graminea*; *Oidium*; *Erysiphe graminis*; *Rhynchosporium secalis*; *Cochliobolus sativus*; *Puccinia hordei*; *Puccinia striiformis*; Germany.

Introduction

In Germany some universities and institutions of the Bund and Länder work on phytopathological problems. The Federal Biological Research Centre (BBA) has six branches including one in Kleinmachnow near Berlin. This branch is on the territory of the former East Germany and has only recently been established. The foundation of this branch enabled a significant extension of testing for resistance to plant diseases.

After wheat, barley is the most important grain in Germany. In 1992, some 1.5 million ha were cultivated with winter barley and 0.9 million ha with spring barley, yielding 5.7 t/ha and 4 t/ha, respectively.

The most important barley leaf diseases in Germany are powdery mildew, leaf rust, net blotch, scald, stripe rust and spot blotch, in that order. Barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) is not important, because the farmers use seed treatment. Here I deal with net blotch (net and spot type), scald and spot blotch.

Net blotch has been reported frequently in West Germany since the mid-1970s, and in East Germany since the 1980s. In 1987, for instance, 56% of the area under winter barley was infected, as was 85% of the area under spring barley. The delayed occurrence in the East might be associated with the later introduction of fungicides. The control of powdery mildew with special fungicides and increased N fertilization resulted in an increase in net blotch infection. Scald attacks also increased in the 1970s and 1980s with the intensification of agriculture. Both net blotch and scald attacks are determined by the weather; they sometimes cause heavy yield losses while at other times they are of no importance at all. Recently, control measures have been used, especially against net blotch, for which efficient fungicides are available. Although spot blotch is of minor importance, it is occasionally reported. In 1982, for instance, the disease caused an unusual stem bending connected with browning of nodes.

في السبعينات، وفي ألمانيا الشرقية في الثمانينات. ومن المفترض أن يرتبط تأخر حدوث الإصابة في الشرق إلى الإدخال المتأخر للمعاملة بالمبيدات الفطرية لمكافحة البياض الدقيقي. وتتأثر بقوة شدة الإصابة بمرض التبقع الشبكي والسفحة بالطقس. وماتزال عملية التربية للمقاومة في ألمانيا في بداياتها، إلا أن الأبحاث جارية لتحديد عزلات من العامل الممرض لكل من مرضي التبقع الشبكي والسفحة ومقارنة المقاومة بين الطرز الوراثية للشعير.

The first institution to deal with net blotch in Germany was Göttingen University, where Mauler finished her work on the disease in 1983. In 1990, summary results on spot blotch were published by Weisig. At Munich University, epidemiological problems of net blotch and scald and host resistance were studied. Results on scald were published in 1984 (Pietsch) and on net blotch in 1988 (Deimel) and 1991 (Brandl). At Bonn University, Werres and Hindorf (1990) have created an epidemiological model to support monitoring and control of scald. This model will be tested in 1994.

At the former Institute for Cereal Breeding in Gülzow-Güstrow, Beer (1985, 1986, 1991) worked on resistance to scald. At the Institute for Phytopathology Aschersleben, Harteb et al. studied resistance to net blotch (Hartleb and Heyer 1988a, b; Hartleb et al. 1990).

Sachs dealt with the monitoring of diseases on agricultural crops, including leaf blights on barley, from 1974 to 1990. At present, I am testing barley for resistance to net blotch and scald.

Most of the barley breeders in Germany have paid little attention to resistance to net blotch as it is difficult to identify symptoms (i.e. the net and spot types). The distribution of the spot type is not well known, and a method for testing resistance under conditions related to those in the field is lacking.

Although the above-mentioned authors have made attempts at resistance breeding, numerous methodical works are needed for routine resistance testing.

First, we carry out simple varietal comparisons with a mixture of isolates. As knowledge of the virulence situation is limited it is necessary to perform systematic virulence analysis.

It is only then possible to perform inoculations with single races. Consequently, resistance testing for net blotch and scald with defined races is expected to be possible only in a few years.

Other scientific institutions of Germany also continue to work on net blotch and scald with emphasis on the research into resistance and resistance breeding.

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Agronomic Performance and Resistance to Net Blotch in Barley Doubled Haploid Lines

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Abstract

Crosses were made between six barley (*Hordeum vulgare* L. subsp. *vulgare*) genotypes. Three F_2 populations and

الكفاءة الزراعية للسلالات الأحادية المجموعة الصبغية المضاعفة ومقاومتها للتبقع الشبكي

الملخص

أجريت تهجينات بين ستة طرز وراثية من الشعير (*Hordeum vulgare* L. subsp. *vulgare*)، واستخدمت ثلاث عشائر من الجيل الثاني F_2 وسلالات أبوية لتحديد مدى توريث المقاومة الجزئية للتبقع الشبكي (*Pyrenophora teres* Drechs.[=*Drechslera teres* (Sacc.) Shoem.]) كما استخدمت نباتات الجيل الأول من كل تهجين لإنتاج سلالات أحادية المجموعة الصبغية المضاعفة بواسطة التهجين البينوعي

parental lines were used to determine the inheritance of partial resistance to net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) and F_1 plants of each cross were used to produce doubled-haploid lines by interspecific crossing (F_1 × *H. bulbosum* L.). In growth-chamber experiments, F_2 populations, doubled haploids and parental genotypes were inoculated and studied to determine the inheritance of resistance to net blotch. Heritability was high (58–69%). Some doubled haploids resistant to net blotch were obtained from the three crosses, doubled-haploid lines resistant to net blotch and with good agronomic performance were produced.

Key words: *Hordeum vulgare*, barley; hybridization; disease resistance; *Pyrenophora teres*.

(F_1 × *H. bulbosum* L.). وفي تجارب غرف النمو، لقحت عشائر الجيل الثاني F_2 والطرز الوراثية الأحادية المجموعة الصبغية المضاعفة والأبوية وتمت دراستها لتحديد مدى توريث المقاومة لمرض التبقع الشبكي، وقد كانت قابلية التوريث عالية(58-69%). تم الحصول على بعض السلالات الأحادية المجموعة الصبغية المضاعفة المقاومة للتبقع الشبكي من التهجينات الثلاثة. كما تم إنتاج سلالات أحادية المجموعة الصبغية المضاعفة مقاومة للتبقع الشبكي وذات كفاءة زراعية جيدة.

Introduction

Barley net blotch caused by *Pyrenophora teres* is widely distributed in France and has reached epidemic proportions over the last ten years (Damay et al. 1982). Two forms are present: *P. teres* f.sp. *teres*, which gives rise to reticulate necrotic lesions (net form), and f.sp. *maculata* Smedegaard-Petersen which causes highly polymorphic necrotic lesions (spot from). The latter may be confused with lesions caused by other pathogens (Barrault 1989). Although both forms are found in the barley-growing regions of France, the *maculata* form usually predominates. The disease has considerable effect on yield and most barley cultivars are susceptible to this pathogen (Barrault et al. 1990). In France, different trials have shown that when disease pressure of the pathogen is severe (f.sp. *maculata*), fungicide application increases yield by 20%.

Reliable laboratory screening techniques can increase the effectiveness of breeding programs by reducing the expense of field testing. A significant relationship between detached-leaf and whole-plant reaction to *P. teres* has been reported (Sharma 1984). The leaf-disk technique was used to determine the genetic variability for net blotch resistance in barley and the results were highly correlated with those from experiments with seedlings or adult plants (Arabi et al. 1991b).

Quantitative resistance to net blotch has been identified in several barley cultivars and genetic factors controlling this resistance have been determined (Khan and Boyd 1980; Bockelman et al. 1977). Use of net blotch resistance may offer considerable advantages in breeding programs and several studies have been conducted to develop net blotch resistant cultivars (Tekauz and Buchannon 1977). A diallel analysis based on five parents and ten hybrids showed that average effects of alleles were more important than dominance in controlling resistance to net blotch (Douglas and Gordon 1985). Furthermore, results of reciprocal crosses among nine barley genotypes in a diallel program showed that partial resistance to net blotch in two genotypes had a high additive genetic effect, and could be used successfully for breeding purposes (Arabi et al. 1990).

Doubled-haploid production in barley using interspecific hybridization between *Hordeum vulgare* and *H. bulbosum* is widely used in selection programs (Jensen 1983; Sarrafi et al. 1986; Wenzel 1985; Rossnagel et al. 1986; Devaux 1986). Rapid production of recombinant resistant lines by the doubled-haploid method has already been used for barley yellow mosaic virus (Foroughi-Wehr and Friedt 1984), powdery mildew (*Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal [= *Oidium monilioides* Desm.]) (Friedt et al. 1984), barley smuts (*Ustilago hordei* (Pers.) Lagerh. and *U. nuda* (Jens.) Rostr.) (Chistyakova 1987) and barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) (Skou and Haahr 1984).

The present study was initiated to determine the genetic gain in resistance to net blotch and some other agronomic characters in doubled-haploid lines of barley obtained from three crosses.

Material and Methods

The cultivars and lines used represented wide genetic variability, especially for net blotch resistance. Massif is a French commercial cultivar; Golf comes from the UK and Smash from Belgium; A79EDO47 is a pure line derived from inter-varietal crosses carried out by ORSEM (a French seed company); CI-5791 is an introduced Ethiopian line, and Arrivate originates from Iraq.

Crosses were made among the six genotypes (Massif × A79EDO47, Arrivate × Smash and CI-5791 × Golf). F_2 populations and parental genotypes were used to determine the inheritance of partial resistance to net blotch and F_1 plants of each cross were used to produce doubled-haploid lines, by

interspecific crossing with *H. bulbosum*. Five experiments, two in growth chambers and three in the field, were performed.

Growth chamber experiments

The growth-chamber experiments were conducted in special culture dishes (60 × 40 × 8 cm) filled with vermiculite. In the first experiment, F_2 plants and their parents were inoculated to determine the inheritance of resistance to net blotch. In the second growth-chamber experiment, all doubled haploids derived from the three crosses, in addition to their parental lines, were used. Seedlings were irrigated with Knop nutrient solution once a day. Temperatures were 23±0.5°C (day) and 18±0.5°C (night) and relative humidity was 85–95%. Light intensity was 60 W/m² with a day length of 12 hours.

Selection for doubled-haploid lines resistant to net blotch was done in the second growth-chamber experiment. Inoculation was performed by spraying 14-day-old seedlings with a mycelium suspension standardized at 10^3 to 10^4 mycelium fragments per milliliter (Barrault 1989). The sprayed seedlings were maintained at 95–100% relative humidity for 48 hours, by covering culture dishes with a special transparent cover. Scoring was performed eight days after inoculation. The second leaf from the top of the main tiller of 12 parental and doubled-haploid lines was removed and foliar discs (14 mm diameter) of each type were inoculated as described by Arabi et al. (1991b). Host reaction in all experiments was rated from 1 (resistant) to 9 (susceptible) as proposed by Barrault (1989).

Field experiments

The three field experiments were planted as randomized blocks with three replications, and plots of one row 1.5 m long. Plants were spaced every 10 cm and rows were 25 cm apart. Each experiment comprised the two parental genotypes of each cross and its selected doubled-haploid lines (Arabi et al. 1991a).

Grain weight/plant was determined from all plants within each replication, except for the first and last border plants. Seeds of the main tillers were used to estimate 1000-grain weight and number of grains/spike. The main tiller was also used for plant height. Date of heading was noted for each replication.

Analysis of variance of the randomized block design was performed for each experiment and means were compared by the Newman–Keuls test.

Results and Discussion

Genetic variability for net blotch resistance in the growth-chamber experiments is summarized in Table 1. Massif and Arrivate were the most resistant, Golf and A79EDO47 were the most susceptible, while Smash and CI-5791 had intermediate values. These results confirm previous studies on resistance of cultivars and lines to net blotch (Arabi et al. 1990, 1992). Heritability of resistance to net blotch in the three F_2 populations was high, from 58 to 69% (Table 1). Quantitative resistance to barley net blotch was also shown by Khan and Boyd (1980) and Arabi et al. (1990).

The field experiments and disk inoculation confirmed the results of the second growth-chamber experiment.

Variability for the various agronomic traits among the parents and di-haploid lines selected for their resistance to net blotch is presented in Tables 2 to 4. Among the parents, Smash and Arrivate had the highest grain weight/plant. These two cultivars and A79EDO47 had the maximum number of grains/spike, while the lowest values occurred in Golf and CI-5791 which are two-rowed types. CI-5791 had the highest 1000-grain weight. Golf was the shortest and Arrivate was the earliest.

Table 1. Net blotch resistance of parental lines and F_2 populations in the growth chamber.

Genotype	No. of plantlets	Mean (1–9)	Variance δ^2	Heritability h^2 (%)
Massif (Mas)	31	1.43	0.46	
A79EDO47	32	4.81	1.58	
(Mas × A79) F_2	199	3.35	3.25	68.65
Arrivate (Ar)	41	2.15	0.48	
Smash (Sm)	91	3.86	1.39	
(Sm × Ar) F_2	272	3.24	2.45	61.83
CI-5791 (CI)	44	3.18	1.13	
Golf (Go)	45	5.31	1.40	
(CI × Go) F_2	202	4.50	3.04	58.38

Table 2. **Some characteristics of doubled-haploid lines resistant to net blotch selected from the cross Arrivate × Smash.**

Genotype	Grain wt/ plant (g)	No. grains/ spike	1000-grain wt (g)	Plant ht (cm)	Days to heading
Arrivate	13.10 bc	49.26 de	52.82 bcd	93.45 b	138.7 f
Smash	14.26 b	57.05 ab	47.17 d	83.33 c	182.0 a
HD5-1†	8.54 d	47.61 de	49.79 cd	91.83 b	154.0 bcd
HD5-3	10.88 bcd	46.26 ef	50.77 bcd	93.66 b	152.7 bcd
HD8-1	8.89 d	51.11 cde	48.73 cd	89.92 b	151.7 cd
HD8-2	9.33 d	55.53 abc	53.66 bcd	86.49 bc	150.3 d
HD8-3	14.03 b	52.87 bcd	56.10 abc	92.80 b	154.0 bcd
HD18-1	9.76 cd	41.64 f	59.29 a	95.92 b	153.7 bcd
HD23-1	11.11 bcd	47.54 de	53.13 abc	91.90 b	145.0 f
HD23-11	12.92 bc	56.49 ab	51.75 bcd	91.62 b	154.7 f
HD25-1	17.00 a	58.83 a	95.32 a	89.21 bc	145.7 f
HD25-2	9.96 cd	45.76 ef	56.86 ab	90.82 b	155.0 bc
HD26-1	13.03 bc	53.68 bcd	53.49 bcd	101.73 b	155.0 bc

† HD = Doubled haploid: first no. = F_1 Plant crossed with *H. bulbosum*; second no. = doubled-haploid line no.
Means within columns followed by the same letter do not differ significantly at P=0.05 (Newman-Keuls test).

Table 3. Some characteristics of doubled-haploid lines resistant to net blotch selected from the cross Arrivate × Smash.

Genotype	Grain wt/ plant (g)	No. grains/ spike	1000-grain wt (g)	Plant ht (cm)	Days to heading
CI-5791	8.47 fg	17.90 fg	62.61 ab	87.68 a	150.3 ab
Golf	8.72 fg	22.39 cd	50.72 c	75.60 cd	153.3 a
HD1-1†	7.95 fg	16.50 g	57.92 abc	71.39 ef	145.7 bc
HD1-3	9.40 ef	18.55 fg	59.23 abc	76.75 b	145.7 bc
HD1-4	9.68 ef	17.97 fg	60.27 abc	74.20 bc	142.7 c
HD3-1	9.29 ef	24.85 b	56.16 abc	70.53 fg	138.3 c
HD3-2	10.58 cd	23.09 cd	53.03 bc	70.03 fg	128.0 d
HD3-3	6.82 g	19.87 ef	62.54 ab	69.22 fg	131.3 d
HD3-4	7.30 g	20.31 ef	65.56 a	70.59 fg	128.3 d
HD3-5	11.00 cd	21.48 de	59.11 abc	72.40 de	129.3 d
HD3-7	8.54 fg	20.04 ef	55.70 abc	68.56 fg	129.7 d
HD4-1	10.30 de	21.72 de	61.42 abc	66.87 fg	137.7 c
HD4-5	11.93 bc	25.08 b	53.39 bc	66.60 gh	143.0 c
HD4-6	12.27 ab	23.70 bc	55.43 abc	67.72 fg	141.0 c
HD7-1	11.79 bc	20.34 ef	57.22 abc	63.53 h	139.3 c

† See Table 2.
Means in a column followed the same letter do not differ significantly at P=0.05 (Newman-Keuls test).

Table 4. Some characteristics of doubled-haploid lines resistant to net blotch selected from the cross Massif × A79EDO47.

Genotype	Grain wt/ plant (g)	No. grains/ spike	1000-grain wt (g)	Plant ht (cm)	Days to heading
Massif	9.91 d	44.53 def	48.06 ab	92.42 a	161.0 ab
A79EDO 47	11.25 bcd	53.95 bc	44.46 bc	83.64 bc	155.7 d
HD15-7†	9.74 d	37.11 f	44.80 bc	86.38 ab	161.3 ab
HD15-8	8.11 d	54.45 b	41.05 c	93.70 a	158.0 bcd
HD15-9	17.64 a	64.17 a	48.13 abc	75.11 c	162.0 ab
HD18-3	7.82 d	36.64 f	52.58 a	80.31 bc	162.0 ab
HD18-5	17.19 a	47.40 cde	45.46 bc	84.28 bc	163.0 a
HD19-1	10.19 cd	40.87 ef	43.21 bc	75.91 c	158.3 bcd
HD19-6	10.33 cd	44.01 def	45.07 bc	80.39 bc	161.3 ab
HD20-5	14.48 ab	49.55 cde	45.79 bc	83.34 bc	160.3 abc
HD20-6	7.76 d	49.64 cde	40.53 c	83.00 bc	156.3 cd
HD22-1	17.65 a	45.18 def	49.00 ab	83.36 bc	158.3 bcd
HD22-2	11.10 bcd	52.60 bcd	44.25 bc	86.30 ab	160.3 abc

† See Table 2.
Means in a column followed by the same letter do not differ significantly at $P=0.05$ (Newman–Keuls test).

Among progeny from the three crosses, some di-haploids had significant genetic gain for grain weight/plant. The doubled-haploid line Massif × A79EDO47-HD15-9 had the highest genetic gain for number of grains/spike (64), and the maximum value for 1000-grain weight came from Arrivate × Smash-HD25-1 (59.32 g) which was significantly better than the best parent, Arrivate (52.82 g). Some di-haploid lines were taller and others shorter than the parental genotypes. For example, Massif × A79EDO47-HD15-9, a productive line with large grains, had a short stem (75 cm) compared with the shorter parent, A79EDO47 (83 cm). Maturity also showed high genetic variability in di-haploid lines and some productive doubled haploids like CI-5791 × Golf-HD3-5 and CI-5791 × Golf-HD3-2 had shorter heading periods (128 days) than the earliest parent (CI-5791: 150 days). Rapid production of recombinant barley lines and selection for productive doubled haploids in breeding programs has also been demonstrated by Wenzel (1985), Jensen (1983) and Sarrafi et al. (1986).

We may conclude that promising lines resistant to net blotch can be obtained by selection in doubled-haploid lines derived from F_1 varietal crosses.

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Barley Leaf Blights in Algeria

أمراض لفحة الأوراق على الشعير في الجزائر

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Abstract

Four cereal disease surveys were conducted during 1989, 1990, 1991 and 1992. They covered all the cereal-growing areas of Algeria. Diseases on barley (*Hordeum vulgare* L. subsp. *vulgare*) were more severe than on wheat (*Triticum* spp.). Barley stripe (*Pyrenophora graminea* S.Ito & Kuribay.[=*Drechslera graminea*.(Rab.) Shoem.]) and spot blotch (*Pyrenophora teres* Drechs. [=*Drechslera* ...

الملخص

أجريت أربع دراسات حصرية على أمراض الحبوب خلال 1991,1990,1989 و1992، وقد غطت جميع مناطق زراعة الحبوب في الجزائر. وكانت الأمراض على الشعير *(Hordeum vulgare* L. subsp. *vulgare)* أكثر شدة منها على القمح (*Triticum* spp.). وكان تخطط الشعير *(Pyrenophora graminea* S.Ito & Kuribay.[=*Drechslera graminea*.(Rab.) Shoem.]) والتبقع الشبكي *(Pyrenophora teres* Drechs. [=*Drechslera*

Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) and net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) were more frequent and more severe than scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) and spot blotch (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem.]). Scald was mostly restricted to southern regions and spot blotch was rarely encountered. Barley stripe is becoming a serious problem with incidence averaging 60%, causing considerable yield losses. Lack of seed treatment is considered the most important factor for the spread of this disease in the country. Screening of seedlings for resistance to *P. teres* and *P. graminea* did not result in the identification of lines with adequate resistance.

Key words: *Hordeum vulgare*; barley; *Pyrenophora teres*; *Pyrenophora graminea*; *Erysiphe graminis*; *Rhynchosporium secalis*; *Cochliobolus sativus*; disease resistance; Algeria.

أكثر تكراراً وشدة من مرض السفحة (Sacc.)Shoem.]) *teres* والتبقع (*Rhynchosporium secalis* (Oud.) J.J.Davis) الهلمنثوسبوري (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast.[=*Bipolaris sorokiniana* (Sacc.) Shoem.]). وكانت السفحة محصورة إلى حد كبير بالمناطق الجنوبية، ونادراً ماشوهد التبقع الهلمنثوسبوري. وقد أصبح مرض تخطط الشعير مشكلة خطيرة عندما بلغ متوسط نسبة الإصابة به 60٪ مما سبب خسائر كبيرة في الغلة. وقد اعتبر غياب معاملات البذور أكثر العوامل أهمية في انتشار هذا المرض في أرجاء البلد. ولم تسفر عملية غربلة البادرات لمقاومة *P. teres* و*P. graminea* عن تحديد سلالات ذات مقاومة تفي بالغرض.

Introduction

Over 3 million hectares of cereals are grown annually in Algeria. This represents 24% of the total cultivated area. The cereal-growing regions are mostly situated in the high plateaux were winters are cold, springs start late, and summers are dry and hot. These regions are characterized by irregular rainfall ranging between 200 and 400 mm. The remaining cereal areas are in costal and sub-costal regions of the country. These regions are more humid (rainfall ranging between 500 and 1000 mm) with warmer winters.

Durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) occupi[es] about 38% of the total area, bread wheat (*T. aestivum* L. [subsp.] *aestivum*) 18%, barley 40% and oat (*Avena sativa* L.) [Techniques Agricoles 1989).

Ce[real] [has] been and still is low. The country imp[orts] [to meet] its needs. Since about 1978, overall pr[oduction] [has] million tonnes/year – an average yi[eld]

[Early] late and low-yielding cultivars are c[ommon] [are] contributing to low yields. The r[elative] [importance] of these factors has been evaluated. F[rom] [a series] of experiments conducted at the I[nternational] [Center] for Cereal Cultures (ITGC) experimental s[tation], sowing dates and fertilizers were t[ested] [for] yield losses. No assessment of the i[mpact] [is] available.

[Fungicides] are not optional for most leaf [diseases] [in] incidence (sometimes reaching epidemic levels) is cyclic. However, it has been suggested that septoria leaf blotch (*Mycosphaerella graminicola* (Fuckel) Schroeter [= *Septoria tritici* Rob. in Desm.]) and rusts (*Puccinia* spp.) are increasing in importance.

Because of the lack of information, cereal disease surveys started in 1989 to help determine the actual status. *Pyrenophora teres* and *Py. graminea* were the most important and, hence, resistance tests were started for both diseases.

Material and Methods

Survey methodology

Surveys covering all the cereal-growing regions of the country were conducted by a group of scientists from Algeria, Tunisia, Morocco and the International Center for Agricultural Research in the Dry Areas (ICARDA). The team followed main roads, stopping every 15 km.

Disease assessment

Disease assessment was based on incidence and severity. Incidence was defined as the percentage of plants infected (per field) and the percentage of fields in which the disease was present. Severity was defined as the intensity of the development of the disease per plant and per field. A group average score was computed for incidence and severity of any disease present. Only results from barley are presented here.

Results

Barley survey

Among the nine barley diseases scored during these surveys, spot blotch occurred only once (in 1992) with very low incidence and severity (Table 1). Scald, though restricted

Table 1. Importance of barley diseases in Algeria, 1989–92.

Year	NB†	BS	SC	SB	PM	LR	CS	LS	BYDV
1989	68 M‡	63 M	19 L	0	12 M	55 S	41 L	7 L	41 M
1990	65 S	50 S	3 M	0	30 M	13 M	32 M	3 L	20 M
1991	80 S	71 S	31 L	0	20 M	0	25 M	12 M	50 M
1992	80 S	70 S	44 M	12 M	15 M	6 L	38 L	9 L	9 M

† NB = net blotch, BS = barley stripe, SC = scald, SB = spot blotch, PM = powdery mildew, LR = leaf rust, CS = covered smut, LS = leaf stripe, BYDV = barley yellow dwarf virus.

‡ Numbers indicate incidence (%) and letters severity (L = low, M = moderate, S = severe).

mainly to southern cereal-growing regions, developed with a moderate incidence and low severity. It was present in 44% of the surveyed fields in 1992. Net blotch was the most prevalent disease over the four years of the survey. Its incidence and severity were high (found in 80% of fields and the attack was severe). Barley stripe occurred yearly and matched net blotch in incidence and severity; it was found in 60% of the fields. Seed-borne diseases like smuts (*Ustilago* spp.) were more important on barley than on wheats. Barley Yellow Dwarf Virus symptoms were common. Leaf rust (*Puccinia hordei* Otth) was severe in 1989 (55% of the surveyed fields). Powdery mildew (*Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal [= *Oidium monilioides* Desm.]) was regularly present on barley but never at high incidence.

Resistance tests

Forty-five barley cultivars screened for resistance at the seedling stage to three Algerian isolates of *Pyrenophora teres* were all susceptible. No sources of resistance occur in Algerian material. Similar results were obtained for *Pyrenophora graminea*.

Discussion

In Algeria, diseases are more common on barley than on wheat. However, more work has been done on wheats than on barley. The most prevalent diseases on barley are barley blights, of which barley stripe is the most important. Seed treatment can, at least as a first step, decrease this disease considerably. Net blotch, though more common than barley stripe, is less damaging.

No defined sources of resistance are available in Algeria to barley leaf blights. Breeding programs should focus more on resistance to these diseases.

Proposed Barley Differentials to Assess Pathogenic Variability in *Rhynchosporium secalis* and *Pyrenophora teres*

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Abstract

Scald and net blotch are important diseases of barley (*Hordeum vulgare* L. subsp. *vulgare*) in most areas of the world where the crop is grown. The causal fungi, *Rhynchosporium secalis* (Oud.) J.J.Davis and *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.), respectively, both exhibit pathogenic variability, but that

طرز وراثية تفريقية مقترحة من الشعير لتقييم التفاوت في القدرة الإمراضية بين *Rhynchosporium secalis* و *Pyrenophora teres*

الملخص

تعتبر السفحة والتبقع الشبكي من أمراض الشعير (*Hordeum vulgare* L. subsp. *vulgare*) الهامة في معظم المناطق التي يزرع فيها المحصول. إن الفطرين المسببين *Rhynchosporium secalis* (Oud.) J.J. Davis و *Pyrenophora teres* Drechs. (=*Drechslera teres* (Sacc.) Shoem.) يظهران على التوالي تفاوتاً في القدرة الممرضة، إلا أن قدرة *R. secalis* قد درست على نحو أوسع بكثير. وتعتبر مقارنة الدراسات الخاصة بعشائر *R. secalis* لرصد مستويات التفاوت وانتشار الأنماط المرضية،

of *R. secalis* has been studied much more extensively. Comparisons of studies of *R. secalis* populations to detect levels of variability and prevalence of pathotypes are problematic, since most researchers have used neither the same lines, nor the same number of barley differentials in their protocols. In addition, the genetic basis for resistance has not been elucidated completely, and the number and identity of host resistance gene(s) reported often differ for the same barley line. To facilitate future comparisons, a core differential set of 10 barley genotypes is proposed; these could be used as part of a larger set, depending on the purpose and geography of the study. The 10 barleys proposed are those that have been most useful in published research in this area. From the relatively few studies that have been done, physiological and pathogenic variability in *P. teres* seems to be based, in large part, on the presence of one, or of both, forms of the pathogens, *P. teres* f.sp. *teres* and f.sp. *maculata* Smedegaard-Petersen. These produce different lesion types, net and spot, respectively, on susceptible hosts. In Canada, 65 pathotypes have been differentiated, but this high level of variability has not been confirmed elsewhere. The genetic basis for resistance to *P. teres* is largely undefined, making the selection of differential genotypes arbitrary. Despite this limitation, seven barley accessions are suggested as a possible differential set; small quantities of seed are available from the Winnipeg Research Station upon request.

Key words: *Hordeum vulgare*; barley; selection; varieties; disease resistance; pathogens; *Pyrenophora teres*; *Rhynchosporium secalis*.

ذات طابع إشكالي نظراً لعدم استخدام معظم الباحثين نفس السلالات أو نفس العدد من الطرز الوراثية التفريقية من الشعير في أنظمتهم البحثية.

وبالإضافة إلى ذلك، لم يتم إيضاح القاعدة الوراثية للمقاومة على نحو وافٍ، كما يختلف غالباً عدد وهوية مورثات العائل المقاومة في سلالة الشعير نفسها. وبغية تسهيل إجراء المقارنات مستقبلاً، اقترحت مجموعة تفريقية رئيسية من 10 طرز وراثية، قد تستخدم كجزء من مجموعة أكبر وفق هدف وجغرافية الدراسة. وإن هذه الطرز المقترحة من الشعير هي الأكثر فائدة في البحوث المنشورة في هذا المجال. ومن الدراسات القليلة نسبياً التي تم إجراؤها، يبدو أن التفاوت الفيزيولوجي والإمراضي لـ *P. teres* يرتكز إلى حد كبير على وجود شكل واحد أو شكلين معاً من العوامل الممرضة، *P. teres* f.sp. *teres* و f.sp. *maculata* Smedegaard - Petersen. وتنتج هذه العوامل أنماطاً مختلفة من الأضرار، شبكية أو تبقعية، على التوالي، على العوائل الحساسة. ففي كندا، تم تمييز 65 نمطاً مرضياً، إلا أن هذا المستوى المرتفع من التفاوت لم يُؤكد بعد في بلدان أخرى. ولم تحدد بعد على نطاق واسع، القاعدة الوراثية لمقاومة *P. teres*. الأمر الذي يجعل من عملية انتخاب الطرز الوراثية التفريقية عملاً اعتباطياً. ورغم هذا التقييد، اقترحت سبعة مدخلات من الشعير كمجموعة تفريقية ممكنة، علماً أن كميات صغيرة من البذور من محطة بحوث وينبيج، متوفرة عند الطلب.

Introduction

Disease management in crops is essential if yields and quality are to be maximized. Of the strategies used to manage disease, genetic resistance is one of the most important. Incorporation of resistance is effective in preventing disease, and may be the most economic means of control.

Due to the significant effects of environment, breeding programs for cereals are often regional and cultivars developed for one locality may not perform optimally elsewhere. In addition to the effects of rainfall, temperature, soil type and day *length*, *cultivar* performance can also be influenced by biological factors such as the presence of pathogens, pests, weeds and of beneficial organisms.

Within regions, pathogens may be sporadic or endemic, and species may be composed of more than one strain or pathotype. Such pathogen "populations" may differ between regions and can also change with time as new pathotypes appear or their proportions alter. Therefore, local pathogen populations should be sampled and characterized routinely, to ensure that appropriate resistances are used in breeding programs, and that progeny are tested with relevant pathotypes.

Variability in a pathogen species is demonstrated when individual isolates produce differential reactions in the host. The pathogen population is composed of a number of "strains," "races" or "pathotypes." The presence and proportion of various pathotypes can be determined by inoculating several host genotypes which have different gene(s) for resistance with individual isolates. Such a group of host genotypes is called a "differential set." The use of a "standard" differential set by researchers aids comparisons of pathogen populations among regions and in accessing desirable resistant germplasm for breeding programs. Standard differential sets have been developed and are used by researchers working on cereal rusts and mildews in North America and Europe, respectively.

In barley, net blotch and scald are important diseases almost everywhere the crop is grown. Yield losses as high as 50% are

possible when conditions are favorable, the host is susceptible and control measures are not used. Chemical control may be uneconomic and the widespread use of pesticides is currently discouraged to assure environmental sustainability. Similarly, cultural control measures may be untenable, as agronomic practices such as conservation tillage to reduce erosion and retain soil moisture, and continuous cropping may increase the risk of disease. Control by genetic resistance is thus becoming more attractive and is being actively pursued in barley breeding programs throughout the world. Pathogenic variability occurs in both scald and net blotch and this must be considered in protocols for resistance breeding. However, standard differential sets to evaluate this variability have not been developed for these pathogens. These would facilitate comparisons of populations and exchange of useful germplasm.

Proposed barley differential sets for the two diseases, preceded by a short review of host resistance genetics, and variability in the pathogens, follow.

Scald

Comprehensive reviews covering all aspects of scald of barley have been published by Shipton et al. (1974) and Beer (1991). Resistance to *Rhynchosporium secalis* was first reported in the 1920s and the first published study on inheritance of resistance appeared in 1929. In 1950, a single dominant gene (currently designated *Rh4*) was identified which confers resistance in the cultivars La Mesita, Modoc and Trebi (Riddle and Briggs 1950). Since then, a number of additional resistance genes have been identified and their inheritance determined (Dyck and Schaller 1961; Evans 1969; Habgood and Hayes 1971; Hansen and Magnus 1973; Starling et al. 1971; Wells and Skoropad 1963). The designated genes for resistance in various barley accessions have been tabulated by Ali et al. (1976), Beer (1991) and Goodwin et al. (1990). Few inheritance studies, however, have been published in recent years.

Pathogenic variability in *R. secalis* was first described from Argentina by Sarasola and Campi (1947) and has subsequently been reported from several other parts of the world. However, the degree of variability varies considerably, with the number of pathotypes differentiated ranging from 2 to 75 (Table 1). Since most studies have not used identical or even the same number of differential genotypes, comparison of results between studies is not easy. The differentials used in 11 selected studies are shown in Table 2. Of the 29 lines listed, 10 have been used quite frequently, suggesting that they are particularly useful in evaluating pathogenic variability in various parts of the world. All studies have also used a single, unique, universally susceptible genotype as part of the differential set.

The differentials usually used have been genotypes for which a gene (or genes) for resistance to *R. secalis* has been proposed. However, such gene designations are not universally agreed. For example, for the 10 most commonly used differentials, a number of interpretations have been proposed (Table 3). Further ambiguity is evident in that other genes, which were not elucidated in the above studies, may be present. When the reactions of La Mesita and Osiris, both described as having the single dominant *Rh4* gene by Dyck and Schaller (1961), were compared, certain isolates were able to differentiate between them (Table 4). Similarly, cvs Brier and Turk, with the same dominant and recessive genes according to Habgood and Hayes (1971), reacted differently to the 17 pathotypes of *R. secalis* present in Italy (Ceoloni 1980). Until additional studies on the genetics of resistance are done, it is inappropriate to substitute, or exclude, a potential differential cultivar because it is listed as having the same gene(s) for resistance to *R. secalis* as another differential.

Table 1. Level of pathogenic variability detected in *Rhychosporium secalis* populations.

Level of var	Origin (country/region)	No. isolates tested	Pathotypes differentiated	Reference
High	USA/California	175	75	Jackson and Webster (1976)
	USA/Idaho, Oregon	94	60	Goodwin et al. (1992)
	Canada/mainly west	111	45	Tekauz (1991)
	Australia/south-west	203	35	Ali et al. (1976)
Intermediate	Canada/Ontario	352	20	Xue et al. (1991)
	Italy	100	17	Ceoloni (1980)
	Czechoslovakia	100	16	Gacek (1982)
Low	Australia/Victoria	319	5	Brown (1985)
	New Zealand	149	4	Cromey (1987)
	England	122	2	Williams and Owen (1973)

Table 2. Barley accessions used as differentials in studies to assess pathogenic variation in *Rhynchosporium secalis*.

Cv/line	Study†											No. times used
	(3)	(8)	(10)	(11)	(17)	(20)	(21)	(32)	(39)	(43)	(44)	
Atlas	x	x	x	x	x		x		x		x	8
Atlas 46	x	x	x	x	x	x	x	x	x	x	x	11
Abyssinian	x	x		x							x	4
Brier	x	x	x	x	x	x	x	x		x		9
Dea						x				x		2
Gospeck	x											1
Hudson	x	x	x	x	x	x	x	x	x	x		10
Kitchin			x	x	x		x					4
La Mesita	x	x	x	x	x	x	x	x		x		9
Modoc	x	x	x	x	x	x	x	x	x		x	10
Nigrinudum	x	x	x									3
OAC Elmira											x	1
Osiris	x	x	x		x		x		x	x		7
Pioneer						x				x		2
Prefect						x				x		2
Psaknon	x											1
Sakigake	x											1
Steudelli	x	x	x		x		x					5
Sultan	x											1
Trebi			x	x	x	x	x			x	x	7
Turk	x	x	x	x	x		x		x	x	x	9
West China	x											1
Wong						x						1
WW X Glabron	x	x		x	x	x	x	x	x	x		9
CI 2376			x		x		x		x			4
CI 3515	x	x							x			3
CI 4364	x	x										2
CI 5831					x		x					2
CI 8618	x											1

† (3) Ali et al. (1976); (8) Brown (1985); (10) Ceoloni (1980); (11) Cromey (1987); (17) Goodwin et al. (1992); (20) Hansen and Magnus (1973); (21) Jackson and Webster (1976); (32) Schein (1958); (39) Tekawz (1991); (43) Williams and Owen (1973).

Table 3. Barley accessions commonly used as differentials and their designated genes for resistance to *Rhynchosporium secalis*.

Name	CI no.	Ref(s)†	Gene(s)‡	No. dominant (+ recessive) genes
Atlas	4118	(13, 37)	*Rh2Rh2*	1
Atlas 46	7323	(18)	*RhRh*	1
		(14)	*Rh3Rh3*	1
		(13, 37)	*Rh2Rh2, Rh3Rh3*	2
		(1)	*Rh3Rh3/RhRh, RhxRhx*	2
Brier	7157	(5, 13, 37)	*RhRh*	1
		(18)	*RhRh, rh6rh6*	1 + 1
Hudson	8067	(18)	*RhRh*	1
		(37)	*RhRh/Rh3Rh3/Rh4Rh4*	1
		(1)	*RhRh/Rh3Rh3, RhxRhx*	2
La Mesita	7565	(13)	*Rh4Rh4*	1
		(29)	*RhxRhx*	1
		(18)	*Rh^4Rh^4, Rh10Rh10*	2
		(2)	*Rh4Rh4, RhxRhx*	2
Modoc	7566	(13)	*$Rh4^2Rh4^2$*	1
		(18)	*RhRh, rh6rh6*	1 + 1
		(29)	*RhxRhx, rhyrhy*	1 + 1
Osiris	1622	(42)	*Rh3Rh3*	1
		(13, 14)	*Rh4Rh4*	1
		(18)	*Rh^4Rh^4, rh6rh6, Rh10Rh10*	2 + 1
Trebi	936	(13, 34)	*Rh4Rh4*	1
		(20)	*$Rh4^3Rh4^3$*	1
		(29)	*RhxRhx, rhyrhy*	1 + 1
Turk	5611-2	(5)	*Rh3Rh3*	1
		(1)	*Rh3Rh3/RhxRhx*	1
		(18)	*RhRh, rh6rh6*	1 + 1
		(13)	*Rh3Rh3, Rh5Rh5*	2
		(29)	*RhxRhx, RhyRhy/rhyrhy*	2
Wisconsin Winter × Glabron	8162	(18)	*Rh^3Rh^3*	1

† (1) Ali (1975a); (2) Ali (1975b); (5) Baker and Larter (1963); (13) Dyck and Schaller (1961); (14) Evans (1969); (18) Habgood and Hayes (1971); (20) Hansen and Magnus (1973); (29) Riddle and Briggs (1950); (34) Shipton et al. (1974); (37) Starting et al. (1971); (42) Wells and Skoropad (1963).

‡ / = or.

Table 4. Reactions of pairs of barley differentials to three populations of *Rhynchosporium secalis*.

	Cv	Pathotype reactions					
		(1)†		(2)		(3)	
		R‡	S‡	R	S	R	S
1	La Mesita	31	4	32	43	10	7
	Osiris	6	29	40	35	17	0
2	Brier	30	5	53	22	1	16
	Turk	27	8	55	20	10	7

† Study (1) 35 pathotypes from Australia (Ali et al. 1976); (2) 75 pathotypes from USA (Jackson and Webster 1976); (3) 17 pathotypes from Italy (Ceoloni 1980).

‡ R = resistant reaction; S = susceptible reaction.

A proposed core set of differentials for assessing pathogenic variability in *R. secalis* populations is shown in Table 5. This limited set is proposed despite reservations. While it may be preferable to include all known genes for resistance (an example is the 24-member differential set tabulated by Goodwin et al. 1990), practicality suggests that a smaller set is more likely to be used by researchers, who would probably want to expand it by adding several regional cultivars when sampling local pathogen populations.

Table 5. A proposed core set of barley differentials to assess pathogenic variability in *Rhynchosporium secalis*.

Cv/line		Resistance gene(s)†
Atlas	CI 4118	*Rh2Rh2*
Atlas 46	CI 7323	*Rh2Rh2, Rh3Rh3*
Brier	CI 7157	*Rh1Rh1*
Hudson	CI 6087	*Rh3Rh3, Rh4Rh4*
La Mesita	CI 7565	*Rh4Rh4*
Modoc	CI 7566	*Rh4Rh4*
Osiris	CI 1622	*Rh4Rh4*
Trebi	CI 0936	*Rh4Rh4*
Turk	CI 5611-2	*Rh3Rh3, Rh5Rh5*
WW × Glabron	CI 8162	*Rh1Rh1*

† alternative gene designations may have been proposed (see Table 3), and other genes may also be present.

The proposed set contains many of the putative genes for resistance to *R. secalis* and includes barley accessions that in individual studies have been resistant to all or most of the *R. secalis* isolates tested on them (Table 5). The set should be used along side a universal susceptible, and may be augmented by local or other cultivars possessing known or unspecified resistance gene(s) which are considered useful or of interest for a particular geographic region. As an example, in western Canada, it would be suitable to use the proposed 10 genotype differential set (for comparison with variability in other regions) along with CI3515 (because this accession along with Atlas 46, was resistant to the greatest number of Canadian *R. secalis* isolates and pathotypes; Tekauz 1991), and several registered Canadian cultivars that have some resistance to scald, i.e. one or more of the 2-rowed spring barleys CDC Guardian and CDC Richard, 6-rowed Duke, Johnston, Leduc, AC Stacey and Winchester, and the winter barleys OAC Elmira and WB168-4. This last group of cultivars would assess the status of resistance currently available. Some cultivars, such as Johnston, have remained resistant in farm fields for as long as 10 years; resistance in one or two of the others has broken down in local situations, usually in an individual farm field (S. Slopek, pers. comm.).

The use of the same differential set of cultivars may not be a guarantee that comparisons between *R. secalis* populations will be meaningful. Several factors may make interpretation difficult, including: (1) the provenance of the named differential cultivars, which may in fact be genetically variable (Ceoloni 1980); (2) differences in aggressiveness of races between regions (Zhang et al. 1987); (3) the inoculation procedures and conditions used (Jackson and Webster 1976); (4) the age and status of the cultures (Hansen and Magnus 1973); and (5) the system of scoring for reaction type. This last factor, rarely discussed in publications, must surely be a problematic one in obtaining consistent results, either between replicates from individual studies, or between different studies. Williams and Owen (1973) are quite candid about this problem, i.e. the difficulty of what to do with "intermediate type" reactions which do not fall clearly within the resistant or susceptible categories.

The difficulty of comparing results of separate studies was addressed by Goodwin et al. (1990), who proposed a new system of nomenclature for *R. secalis* pathotypes. Their system, based on "octal notation" (a maximum of 8 digits describes the reactions induced by a pathotype), can be used to convert previously-identified, and non-uniformly named, pathotypes of *R. secalis* to a common nomenclature. A positive feature of their system is that missing data, i.e. the use of fewer or different barley differentials, can be accommodated. However, missing data may still make meaningful comparisons of previous populations of *R. secalis* difficult. Nonetheless, this nomenclature should be used in all future studies, both for its commonality and its inherent information.

Some other questions regarding *R. secalis* pathogenic variability remain, including what constitutes a "population," and how results obtained are to be interpreted in formulating breeding strategies. Goodwin et al. (1992) compared *R. secalis* populations in two adjacent western states, Oregon and Idaho, and in Pennsylvania in the eastern USA. They found that both western populations are pathogenically highly variable, but different from each other, while the eastern population had very little variability. Most of the pathogenic variability found in the western populations appeared to be unnecessary, and probably did not develop as a result of host selection. The gene flow between *R. secalis* populations appears to be limited. This is not surprising, since fungal conidia are primarily dispersed by rain-splash. Clearly, each local population of *R. secalis* must be sampled, and results from one region, even if relatively near, cannot substitute for another.

Breeding barley lines with single-gene resistance to *R. secalis* in areas where pathogenicity is highly variable is

unlikely to be effective. Even when it is effective initially, the resistance is unlikely to be durable. The most resistant barley differentials used in previous studies have been those with two or more putative resistance genes (e.g. Atlas 46, Osiris, Turk). Therefore, multigenic resistance to *R. secalis* is a valid goal for barley breeding programs. However, little is known about temporal changes in the pathogenicity spectrum within a region and how *R. secalis* maintains intrapopulation pathogenic variability. There is much still to be done to understand this very complex host/pathogen system. Effective and durable strategies for genetic control of scald may not be possible until this information is known. In the interim, the level of resistance available in current genotypes, combinations of these, and selection of breeding material with quantitative traits that reduce disease development and/or express tolerance will have to suffice. In the absence of any of these inherited traits, the use of foliar fungicides to protect the crop, and of cultural means that reduce levels of inoculum, will have to be used to facilitate barley production in areas where scald occurs.

Net blotch

A detailed review of net blotch of barley was published by Shipton et al. (1973), including a discussion of the genetics of host resistance and occurrence of physiologic races in *Pyrenophora teres* up to that time. Contemporary studies on the genetics of resistance were commenced by Schaller (1955), who described the major gene *Pt* conditioning resistance to *P. teres* in the Manchurian cv Tifang. A few other *Pt* genes were subsequently identified in other barleys of Manchurian origin. Khan and Boyd (1969) found single-gene resistance to Australian *P. teres* race W.A.-2, but not involving *Pt* to Pt_3 previously identified in California. As with scald, there are relatively few recent reports on the genetics of resistance to *P. teres*. However, Arabi et al. (1990) and Douglas and Gordon (1985) have shown that partial resistance and the average effects of alleles, respectively, can be inherited, and that these can be important factors in conditioning resistance to *P. teres* in barley. The complicating factors of environmental effects and genetic background on the expression of resistance by specific genes is outlined by Khan (1969). Tekauz and Buchannon (1977) found an effect of temperature during inoculation and subsequent incubation, on lesion development (resistance expression) in barleys infected by *P. teres* f.sp. *maculata*.

Buchannon and McDonald (1965) demonstrated that Ethiopian barleys, as well as others, were excellent sources of resistance to *P. teres* isolates from Canada, Mexico and the USA. One of these accessions, CI 5791, has also proved resistant to Australian (Khan 1969) and French isolates (Arabi et al. 1990). CI 5791 continues to be resistant to most Canadian isolates of *P. teres* f.sp. *teres* and many of those of f.sp. *maculata* (Tekauz 1990) and has been used as a parent in crosses made to develop agronomic cultivars with effective resistance to *P. teres* in western Canada (Tekauz, unpublished data).

Pathogenic variability in *P. teres* has been known since 1949 (Pon 1949), but little detail was provided. Differences in pathogenicity were subsequently reported between Canadian and Californian isolates (Buchannon and McDonald 1965), and three races of *P. teres* were differentiated in Australia (Khan and Boyd 1969).

The spot form of *P. teres* was reported to occur in Canada and Israel by McDonald (1967), who had first obtained an isolate from Manitoba, Canada in 1954 (W.C. McDonald, pers. comm.). This form was subsequently reported to be common in Scandinavia (Hansen and Magnus 1969; Olofsson 1976; Smedegaard-Peterson 1971) and was designated as *P. teres* f.sp. *maculata* (and the net form as *P. teres* f.sp. *teres*) by Smedegaard-Petersen (1971) in Denmark. *Pyrenophora teres* f.sp. *maculata* is widespread in western Canada (Tekauz 1990; Tekauz and Buchannon 1977), and occurs in Australia (Khan and Tekauz 1982), Montana, USA, and Morocco, Tunisia and Turkey (Karki and Sharp 1986), Germany (Brandl and Hoffman 1991) and South Africa (Scott 1991). However, in South Africa the pathogen causing spot-type lesions has been identified as *P. japonica* Ito & Kurib.

Evidence for pathogenic variability in *P. teres* f.sp. *maculata* was found in the studies by Tekauz and Mills (1974), on Canadian isolates, and by Khan and Tekauz (1982) for Canadian vs. Australian isolates. Variability has also been reported by Karki and Sharp (1986), but was not detected in German spot-type isolates tested by Brandl and Hoffmann (1991).

A high level of pathogenic variability was reported among 182 f.sp. *teres* and 42 f.sp. *maculata* isolates in Canada, and 45 and 20 pathotypes were differentiated, respectively (Tekauz 1990). This level of variability had not been found in previous studies. However, 13 races of *P. teres* f.sp. *teres* (indicating a moderate level of variability) were differentiated in Germany by Brandl and Hoffmann (1991), and ongoing work using molecular techniques suggests that genetic diversity within and between *P. teres* populations is high (T. Peever, pers. comm.). Additional studies of this type are needed to confirm the levels of pathogenic variability in populations of *P. teres*.

A differential set composed of seven barley genotypes is listed in Table 6. The genotypes included can differentiate between the two forms of *P. teres*, and have been useful in differentiating variability in Canadian isolates of both forms. These have been chosen based on the results of a Canadian study (Tekauz 1990), and their choice is arbitrary. Small

amounts of seed will be made available to researchers who request them. This set, if used by others, should be augmented by other barley genotypes known to express differential reactions to the local *P. teres* population. Note that only spring barley genotypes are included in the core differential set.

Table 6. A proposed core set of differential barley lines to assess pathogenic variability in *Pyrenophora teres*.

Cv/line	Synonym
CI 5791	
CI 9214	
Heartland	PI 145351
Leduc	-
OAC 21	CI 1470
Steptoe	CI 15224
TR 473	

In western Canada, agronomically-suitable barley lines with good resistance to both *P. teres* f.sp.*teres* and f.sp. *maculata* are currently being evaluated in pre-registration tests. To date, partial resistance to only one form of *P. teres* has been available in registered Canadian barley cultivars. If *P. teres* populations are as variable as those of *R. secalis*, resistance to *P. teres* may similarly be short-lived. However, the experimental lines with "dual" resistance to *P. teres* have resistance from at least two sources, each having good resistance to one of the *P. teres* forms and partial resistance to the other. If such resistance is multigenic, it may be effective and relatively durable. Studies on the genetic basis of resistance are underway.

It would also be useful for interested colleagues to contact other researchers, i.e. Dr O. Afanasenko, who has done considerable work on *P. teres* pathotypes and the genetics of resistance, but whose research is published in the Russian/Soviet literature and may not be well-known. A more global differential set for *P. teres* may result from such consultations.

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Reactions of Turkish Barley Cultivars to *Pyrenophora graminea* Isolates

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Abstract

Barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) causes significant losses to barley (*Hordeum vulgare* L. subsp. *vulgare*) in Central Anatolia, Turkey. To determine the variation in resistance to barley stripe present in Turkish material, seeds of 53 barley genotypes were tested with two Turkish isolates of *P. graminea*. Diseases symptoms were recorded from six-week-old plants. Three entries were completely immune to the disease (i.e. showed no visible symptoms), and a further two were resistant (<5% symptoms).

Key words: *Hordeum vulgare*; barley; seed testing; genotypes; disease resistance; *Pyrenophora graminea*; symptoms; Turkey.

Introduction

Barley is one of the most important crops in Turkey with 3.45 million hectares cultivated and 2.09 million tonnes annual production (FAO 1991); the area is increasing each year.

Barley stripe disease is of major importance in Central Anatolia. In Ankara province during 1989–91, disease levels were 9.4, 2.3 and 6.2%, respectively, and led to significant losses over the total area of production.

In the early part of the 20th century, barley stripe was widespread. Mercurial fungicides, introduced in the 1920s, reduced the importance of leaf stripe. Today, non-mercurial fungicides prevent attack, but the danger of resistance to fungicides and efforts to reduce their use in agriculture has increased interest in resistant cultivars (Smedegaard-Petersen and Jorgensen 1982).

When breeding for resistance to *P. graminea*, it is essential to know the variation in the pathogenicity of the fungus and in the resistance of existing barley cultivars. Leaf stripe fungus may show physiological specialization (Isenbeele 1930; Christensen and Graham 1935; Amy 1945; Sing and Seksena 1975; Mohammad and Mahmood 1976; Matz and Scharen 1979). A detailed study on Turkish cultivars and physiologic strains of *P. graminea* has been carried out in the Central Antolian Region.

This paper describes the reactions of 53 barley genotypes to two isolates of *P. graminea*.

Material and Methods

Infected leaves were collected from barley fields in Central Anatolia. Two isolates of *P. graminea* were selected and used in this study. Single-spore cultures of the isolates were obtained after blotting infected barley leaves to induce sporulation. Isolates A and B were obtained from barley fields in Sivrihisar (Afyon) and Bala (Ankara), respectively.

Trials were randomized blocks with three replicates, each having 10 seeds for each isolate. Barley seed of 53 cultivars and lines was inoculated with the two isolates using the modified technique of Hammouda (1986). Barley seed was surface-sterilized in 1% sodium hypochlorite for 10 minutes and dried for 3–4 h. Surface-disinfected seeds were placed on an active 8-day-old mycelial culture on potato dextrose agar in petri dishes and incubated at 25°C for 10 days. The entire contents of petri dishes were removed carefully and planted in pots. Pots were transferred to climate rooms at 23±3°C, 60–70% relative humidity with a 15-hour day. Emerged seedlings were examined at two, four and six weeks for symptoms of leaf stripe; data from the 6-week-old plants are reported here.

ردود فعل أصناف شعير تركية إزاء عزلات *Pyrenophora graminea*

الملخص

يسبب تخطط الشعير *(Pyrenophora graminea* S.Ito & Kuribay. [=*Drechslera graminea* (Rab.) Shoem.]) خسائر كبيرة في الشعير *(Hordeum vulgare* L. subsp. *vulgare)* في وسط الأناضول بتركيا. ولتحديد التباين في مقاومة تخطط الشعير الموجود في المادة التركية، تم اختبار بذور من 53 طرازاً وراثياً من الشعير إلى جانب عزلتين تركيتين من *P. graminea*. وقد سجلت أعراض المرض على نباتات عمرها ستة أسابيع، وتمتعت ثلاثة مدخلات بمناعة كاملة ضد المرض (اي لم تظهر عليها أية أعراض)، في حين كان مدخلان آخران مقاومين (أقل من 5% من الأعراض).

Table 1. Reaction of 53 barley cultivars and lines inoculated with two single-spore isolates of leaf stripe fungus *Pyrenophora graminea*.

Cultivar/line	Percentage of leaf stripe†		Reaction‡
	Isolate A	Isolate B	
Gem	8.6	47.5	S
Kaya	14.1	9.5	I
Yerçil	11.7	0	I
Zafer	65.8	17.8	S
Yeşilköy	10.6	0	I
Cyprus Blank A/CI5134	0	10.6	I
3 (number unknown)	0	0	R
88039	11.2	19.0	S
Tem	21.9	33.9	S
H 252	11.9	27.1	S
Avrupaç 2308 5.6955	10.5	23.7	S
Manchuria	9.7	20.6	S
Hannchen	4.9	4.3	R
Varunda/Rupal Ca 324-75	23.4	15.8	S
WI 2291	23.7	0	S
Mentana 85	0	16.8	I
Glda "5"	0	7.3	I
Ca 37906	31.7	20.3	S
Ca 923908	2.3	27.1	S
Ca 7095503	0	31.7	S
Ack × (Rupal × Ant 13-13) Ca 001023	42.2	10.5	S
Trimph × Tura Ca 706912	38.0	31.7	S
Roho/Julia	33.9	29.2	S
Faiz	19.0	7.3	S
As 46/Ath. 2	27.1	21.9	S
Roho/Masurka 1	0	0	R
Roho/Masurka 2	27.1	0	S
WI 2274 (CI 3576x Union) Union (CBC 74-75)	0	21.9	S
Baladi 16/CI 5328 SEA-3-215-15-25-05	11.9	0	I
Aramir	35.6	7.3	S
SEA-290-125-15-05	21.9	21.9	S
Soutora "S" (Sel-5AP-OAP)	47.5	27.1	S
Ca 4625	59.4	0	S
SEA-289-115-25-05	27.1	13.6	S

Table 1. Reaction of 53 barley cultivars and lines inoculated with two single-spore isolates of leaf stripe fungus *Pyrenophora graminea* (continued).

Cultivar/line	Percentage of leaf stripe†		Reaction‡
	Isolate A	Isolate B	
CR 259/36	27.1	13.6	S
Hosta/P12900 (SEA-217-135-15-05)	31.6	21.5	S
Listesiz	0	0	R
Come (from Ecuator)	16.0	11.9	I
Kervana/Masurka IVB 77-0369-5AP-OAP	0	4.9	R
Kym	27.1	34.5	S
Ca 917 177	0	23.7	S
CMB 78-748-11y-500B-501B-502 Y-OB	7.9	0	I
Atem	38.0	4.7	S
Lignee 131	33.5	0	S
Kervana/Masurka (ICB7-0369-4AP-2AP-OAP)	44.3	27.1	S
WI 2198 /Emir	29.7	31.7	S
Roho/Delisa	47.5	70.0	S
ESP/1808-4L//WW.CILLO	9.5	28.5	S
Ca 3473/Kefi (Ca 813703)	11.9	7.8	I
Soufora-03	47.5	27.3	S
Birka	79.2	31.7	S
Ca 70913	38.0	11.8	S
Trimph/Menuet (Ca 70945)	12.2	6.8	I

† Percentage of emerged seedings exhibiting symtoms of leaf stripe.
‡ R= resistant (<5.0% leaf stripe); I= intermediate (5.0 to 17% leaf stripe); S= susceptible (>17.0% leaf stripe) (Tekauz 1983).

Results and Discussion

In the inoculation tests with two isolates of *P. graminea*, the percentage of seedlings showing symptoms of barley stripe differed among entries from 0 to 79%. Three entries were immune, with no evidence of stripe symptoms and two others had stripe symptoms less than 5% (resistant), 11 had an intermediate reaction (stripe symptoms 5–17%) and the rest were susceptible (more than 17% symptoms) (Table 1).

Birka was also found to be susceptible by Tekauz (1983); Kline (1972) reported Manchuria susceptible and Hannchen resistant.

Some spring types are immune to or posses high levels of resistance to *P. graminea*. Similar levels of resistance can be incorporated into adapted and widely cultivated susceptible cultivars.

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Barley Leaf Blights in Australia and New Zealand: Historical Perspective and Current Situation

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Abstract

Barley (*Hordeum vulgare* L. subsp. *vulgare*) is an important crop in Australia and New Zealand and is grown in a wide range of environments. In southern regions of Australia, scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) is the principal leaf disease affecting yield. Numerous studies have been carried out on scald covering pathogen variability, survival, infection and yield losses. Projects are in progress to transfer resistance from related *Hordeum* species as well as on the better use of available resistance in adapted lines. Net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) is significant in New Zealand and Western Australia and occurred historically over all of southern Australia. In most regions the disease is kept in check through the use of resistant varieties, seed treatments and rotation. Early seeding in the higher-rainfall areas of Western Australia has allowed net blotch to become a more severe problem. Only the net form is important. Barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) is rarely seen, although it has recently been observed in Western Australia where isolates insensitive to triadimenol seed treatment have been found. Spot blotch (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem.]) is only a problem in central Queensland. Little work other than screening has been carried out, as the area sown to barley there is small. Three less known barley blights caused by *Pyrenophora/ Drechslera* species, *P. semeniperda* Shoemaker and *D. wirreganensis* Wallwork, Lichon & Sivanesan also occur. The paper reviews the work conducted on these diseases

أمراض لفحة الأوراق على الشعير في أستراليا ونيوزيلاندة : التاريخ والواقع الراهن

الملخص

يعتبر الشعير *(Hordeum vulgare* L. subsp. *vulgare)* محصولاً هاماً في أستراليا ونيوزيلاندة حيث يزرع في نطاق واسع من البيئات. ففي المناطق الجنوبية من أستراليا، يعتبر مرض السفحة *(Rhynchosporium secalis* (Oud.) J.J. Davis) المرض الورقي الرئيسي الذي يؤثر على الغلة. وقد نفذت دراسات متعددة على السفحة غطت تنوع العامل الممرض، المحافظة على بقائه، العدوى والفاقد في الغلة. وتعد المشاريع حالياً لنقل المقاومة من الأنواع المتعلقة بـ *Hordeum*. فضلاً عن مشاريع حول الاستخدام الأفضل للمقاومة المتوافرة في السلالات المتكيفة. ويعتبر التبقع الشبكي *(Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]) على جانب كبير من الأهمية في نيوزيلاندة وأستراليا الغربية، كما ينتشر تاريخياً في عموم منطقة جنوبي أستراليا. وفي معظم المناطق، يكبح المرض عن طريق استعمال الأصناف المقاومة ومعاملات البذور والدورات الزراعية. وقد أدت الزراعة المبكرة في المناطق الأوفر أمطاراً من أستراليا الغربية، إلى جعل التبقع الشبكي مشكلة شائكة أكثر فأكثر. ويعتبر الشكل الشبكي فقط هاماً. أما تخطط الشعير *(Pyrenophora graminea* S.Ito & Kuribay. [=*Drechslera graminea* (Rab.) Shoem.]) ، فنادراً ما يشاهد على الرغم من ملاحظته في الفترة الأخيرة في أستراليا الغربية حيث تم الكشف عن عزلات غير حساسة لمعاملة البذور بالتراديمينول. كما يعتبر التبقع الهلمنثوسبوري *(Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast [=*Bipolaris sorokiniana* (Sacc.) Shoem.]) مشكلة في وسط كوينزلاند فقط. وقد نفذت أبحاث محدودة باستثناء عملية الغربلة لكون المنطقة المزروعة بالشعير هناك محدودة. وتنتشر أيضاً ثلاث لفحات على الشعير معروفة على نطاق

in Australia and New Zealand and also refers to work in progress and planned.

Key words: *Hordeum vulgare*; barley; heritability; disease resistance; *Pyrenophora teres*; *Pyrenophora graminea*; *Rhynchosporium secalis*; *Cochliobolus sativus*; Australia; New Zealand.

Pyrenophora/Drechslera, ضيق تسببها انواع
P. semeniperda Shoemaker/ *D. wirreganensis* Wallwork,
Lichon & Sivanesan. وتستعرض هذه الورقة الأبحاث المنفذة
حول هذه الأمراض في أستراليا ونيوزيلاندة، كما تشير إلى
الأبحاث الجارية والمقررة.

Introduction

Barley is an important crop across Australia and New Zealand. The cereal belt in Australia lies mostly between 23° and 38°S and in areas with rainfall ranging from 250 to 700 mm. The area sown to barley in Australia averaged across the years 1986–91 was 2.435 million hectares and this produced 2521 million tonnes of grain delivered for malting and animal feed as well as straw and grazing feed. South Australia is the major barley-producing state with 915,000 ha sown in the 1986–91 period. It is followed by Western Australia (463,000 ha), New South Wales (452,000 ha), Victoria (421,000 ha) and Queensland (175,000 ha); Tasmania grew only 9000 ha. In New Zealand, barley is mostly grown between 40° and 46°30′ S with rainfall ranging from 500 to 1000 mm. The area sown to barley in New Zealand in 1992 was 100,000 ha producing 430,000 tonnes of grain.

The diseases covered in this review are scald (*Rhynchosporium secalis*) and the leaf blights caused by species of *Pyrenophora* and *Cochliobolus*. Scald is the most damaging leaf disease of barley across southern Australia and New Zealand (Table 1). Net blotch is a significant problem in Western Australia and New Zealand. The other species cause some damage in limited areas but are not a serious problem at present.

Scald

Importance

Scald is a common disease throughout southern Australia. In this region, spring barley is sown in May–July and harvested in early November–January. The disease is most prevalent in areas where barley is more common, where crops are sown early, are thicker and when spring rains permit the spread of spores up the plant. In New Zealand, scald is a major problem in winter barley, but only a problem in spring barley in wet seasons.

In Western Australia, losses up to 48% have been determined from fungicide trials where sprays have been applied at the 6–7 leaf stage (Khan 1986). In 11 spray trials using 'Schooner' barley in South Australia in 1992, yield gains of between 1 and 47% (average 24%) were recorded (Jeffries, pers. comm.). Similar losses (i.e. 1–32%) have been observed in commercial crops in wet seasons. In New South Wales, spray trials conducted between 1985 and 1990 showed an average yield difference of 25% in 'Clipper' between sprayed and unsprayed treatments (Read, pers. comm.). Similarly, surveys in Victoria revealed yield losses of 10–15% in 3 years out of 5 with individual crops recording losses as high as 45% (Brown 1985).

Table 1. Importance of leaf blights of barley in Australia and New Zealand.

Disease	Western Australia	South-eastern Australia	Queensland	New Zealand
Scald	severe	severe	trace	severe
Net blotch	moderate	trace	moderate	moderate/severe
Spot blotch	absent	absent	moderate	moderate
Barley stripe	trace	absent	absent	absent
Arno Bay blotch	trace	moderate	absent	absent
Ring spot	minor	minor	absent	absent
Wirrega blotch	trace	minor	absent	absent

Management

Southern Australian summers are mostly dry which reduces the breakdown of stubble of barley and barley grass (*Hordeum murinum* L. subsp. *leporinum* (Link) Arcangeli) between crops. This, and the trend towards stubble retention and minimum cultivation across much of Australia, provides good conditions for the survival of scald inoculum from one season to the next (Mayfield and Clare 1984a). Crop infection can originate from inoculum carried over from a previous barley crop, from pastures containing volunteer barley or barley grass, or from the edges of fields where one or more hosts are growing. Trials by Mayfield and Clare (1984b) showed that stubble management and cropping sequence were important determinants of plot infection in seedlings.

Scald is more severe in early-sown crops and infection occurs even where paddock history suggests that infection should be very low. Long-distance airborne inoculum is most likely responsible. Ayesu-Offei and Carter (1971) in South Australia showed that conidia could be caught in a spore trap 60 cm above the ground. While most spores were trapped during periods of rainfall, conidia were trapped under windy, but rainless conditions following rain. This could account for long-distance dispersal of the disease, but does not explain why such dispersal is less common later in the season. Mayfield and Clare (1984a) suggest that stubble breakdown and associated loss of viability of scald inoculum following rainfall during autumn (fall) could explain the reduced incidence of scald in later-sown barley in South Australia. Alternatively, this pattern of dispersal is similar to that of septoria tritici blotch (*Mycosphaerella graminicola* (Fuckel) Schroeter [= *Septoria tritici* Rob. in Desm.]) in wheat and it remains possible that an as yet undiscovered teleomorph produces ascospores in autumn enhancing long-distance spread.

The advent of effective herbicides such as trifluralin and Hoegrass (diclofop) controlling ryegrass in the mid-1970s and then Glean (chlorsulfuron) and Ally (metsulfuron) controlling broad-leaved weeds in the 1980s, has allowed farmers to sow barley much earlier. In South Australia, most crops are now sown by the end of May, whereas 10 years ago they would not have been sown much before the end of June.

Changes in rotation and the widespread use of 'Galleon' barley, which has resistance to cereal cyst nematode (*Heterodera avenae* Wollenweber) – a widespread problem in south-eastern Australia –, have led to a reduction in crop damage from root diseases on many farms.

Improved root-disease control, earlier sowing and increased use of nitrogen in some areas have resulted in denser crops, higher yields and, consequently, a greater incidence of scald.

Chemical control

Seed treatments with triadimenol (Baytan) and flutriafol (Armour) are recommended in the higher-rainfall disease-prone areas, to suppress both scald and powdery mildew (*Erysiphe graminis* DC. ex Mérat [= *Oidium monilioides* Desm.]). These treatments are now widely used in Australia in high-risk areas. Khan (1986) demonstrated a 16% yield increase using triadimefon (Erex) as a seed treatment in Western Australia. In South Australia, trials over 11 sites in 1992 showed an average yield gain of 4% where triadimenol was applied to control scald (Jefferies, pers. comm.).

Foliar sprays have been widely used in New Zealand, but have been considered uneconomic in the low-input farming systems of Australia. However, with recent improvements in farm management, many of the higher-rainfall areas in Australia are now producing higher yields and there are likely to be many instances where a foliar spray is economic.

Pathogen virulence

Several studies on collections of field isolates have revealed a wide range of pathotypes. In an investigation into the pathogenicity of 203 isolates of scald collected across Western Australia, South Australia and Tasmania, Ali et al. (1976) identified 35 pathotypes on the basis of their reactions on 21 barley cultivars. Brown (1985), in a study of 319 isolates from barley leaves collected in Victoria, identified five pathogenicity groups using 15 differential barleys. Spores of different pathogenicity groups were even collected from the same lesion.

A smaller investigation in New Zealand by Cromey (1987) revealed only four 'races' from 149 isolates using seven New Zealand cultivars and 11 international differentials. None of these pathotypes carried virulence for more than one differential, suggesting that in the absence of the resistance genes being used commercially in New Zealand there has been little selection for increased virulence complexity. In Australia (Ali et al. 1976), a wide range of more complex pathotypes occurred even though the range of resistance present in the then commercially grown varieties was narrow.

Ali (1981) and Brown (1990) demonstrated high variability in scald isolates from barley grass, which is widespread across the Australian cereal belt. Ali (1981) identified 20 pathotypes from 150 isolates based on their reactions on 20 barley grass biotypes and suggested that this explained the considerable variation in virulence found in the scald population in Australia. Brown (1990) identified 19 pathotypes of scald from 182 single-spore isolates from *Hordeum leporinum*.

It has been suggested (Jackson and Webster 1976) that single isolates change their virulence in culture. In South Australia, tests with single-spore isolates on 20 differentials

found that virulence can remain stable over time (Whisson, pers. comm.). Whisson also found, using multiple-copy probes on single-spore isolates, that the isolates can be identified from their banding patterns and that these are stable although some minor variation is seen. This work aimed to produce a wide range of identifiable races, that would be useful for genetic and molecular studies of the scald fungus and which can be used to assist in pyramiding resistance genes into barley.

Screening and breeding

Screening for resistance to scald in field nurseries is included in the breeding programs in South Australia, Western Australia, Victoria and New Zealand. In New South Wales, naturally occurring infection in trials is assessed.

The great variability in virulence has made it difficult to obtain satisfactory resistance in the field. As with many other pathogens, there have been numerous examples of resistance failing after limited periods of cultivation. Three methods for overcoming this problem are being pursued in Australia and New Zealand.

First, by using resistance from wild *Hordeum*, Abbott et al. (1992) identified nine single dominant genes from *H. vulgare* subsp. *spontaneum* (C.Koch) Thell. in 15 backcross (BC_3) lines with barley cv Clipper on chromosomes 1, 3, 4 and 6. Further crosses and linkage data indicated that at least five genetically independent resistances are available in their material. Brown (pers. comm.) has been pyramiding these resistances into Clipper using allozyme markers. Lines with up to two genes are being evaluated in the field and also used as parents in crosses with more desirable genotypes. Because these allozyme markers are not very closely linked, Brown is now seeking closer-linked RFLP markers on chromosomes 4 and 6 to improve the reliability of screening for these genes.

In New Zealand, Pickering et al. (1987) are using *H. bulbosum* L. as a source of variation for a number of characteristics. Selections with resistance to scald have been identified and are being back-crossed into locally adapted cultivars. They have also produced 31 single-monosomic substitutions involving chromosomes 1, 2, 4, 6 and 7 as well as seven double- and one triple-monosomic substitution plants; these are being screened to locate resistance genes on particular chromosomes (Pickering, 1992 and pers. comm.).

Second, Brown (1989) investigated 'slow scalding' – lines that required longer periods of leaf wetness in the glasshouse for infection to succeed and which showed lower levels of disease with three different isolates. Several promising resistance sources were identified and these were crossed with better-adapted lines. Progeny from these crosses await evaluation in the field.

A third methodology being pursued is to try to accumulate partial resistances already present in well-adapted varieties and advanced breeding lines, with the aim of producing improved varieties with polygenic resistance. Experience in many crops has shown that resistance of this nature is likely to be durable. Ali (1972) suggests that transgressive segregants with improved resistance to scald were easily obtained. He proposes that what he calls "general resistance" was common in progeny and probably involved cuticular resistance to infection. It is essential that where a strategy of utilizing gene pyramids is pursued, there is also a program aimed at providing adequate general or background resistance. This is to provide insurance should the genes in a major gene-pyramiding strategy fail to control the pathogen.

Epidemiology

Brown (1991) studied the conditions required for natural infection in the field in Victoria to define potential scald infection periods. This showed that the standard conditions used in glasshouse screening – 48 hours of leaf surface wetness at 15–20°C – were inappropriate because such conditions are rarely met in the field in Victoria. He suggests that shorter, cooler infection periods would be more useful for detecting field resistance.

Net blotch

Importance and control

Net blotch of barley is principally found in New Zealand and Western Australia and to a lesser extent in Queensland. It is rarely seen in the other southern states although it has been more of a problem in the past when very susceptible varieties were grown.

In New Zealand, net blotch appears to be mostly seed borne and was effectively controlled by organo-mercurials until the banning of these chemicals in 1971. Captan, which was the first replacement, was not effective against net blotch and disease incidence rose to 100% with crop losses up to 25% in the Canterbury and Manuatu areas (Arnst 1981). Net blotch became the most important disease of barley until 1978 when the seed treatments Vitaflo (carboxin), Dithane M-45 (mancozeb), Granosan (mainly mancozeb) and Baytan (triadimenol) became available and the incidence of net blotch decreased to a low level, although it remained a problem around Canterbury where some captan treatments continued to be used.

A triadimenol-resistant isolate of net blotch, probably from an introduction on seed, was found in 1982/83 (Sheridan and Grbavac 1985). This isolate proved very fit and became widespread. This led to the inclusion of imazalil with triadimenol seed treatments in 1984/85. Evaluation of 42 isolates of net blotch by Sheridan and Nendick (1989) in 1987

and 1988 revealed that 65% of isolates, all net type, were resistant to both triadimenol and flutriafol when grown in amended agar. There was also evidence of some isolates becoming less sensitive to imazalil. A survey in 1989 of barley in the Wairapa area (New Zealand), where all seed was treated with imazalil, found no net blotch (Sheridan 1991), although net blotch was still found in the South Island.

Net blotch is rarely a problem in New Zealand now and most outbreaks can be explained by untreated infected seed, or the proximity of crops to infected stubble, barley straw, or volunteer plants (Cromey, pers. comm.). Barley grass is not thought to contribute to the survival of the disease (Cromey, pers. comm.). Where infection occurs crops are likely to be sprayed with propiconazole.

Spot-type net blotch was first found in New Zealand in 1985/86 (Sheridan and Nendick 1987) but is not a significant problem.

In Western Australia, net-type net blotch was recognized as an important problem in the mid-1960s. Its incidence was reduced from 1973 onwards when the resistant cultivar Clipper began to replace the susceptible cultivars Dampier and Beecher. Since then the release of susceptible cultivars and changed management practices have seen the disease increase in importance again. Surveys conducted by Brown (1981) and Khan (1981) in Western Australia showed that net-type net blotch was more common in the warmer and drier northern and eastern regions of the cereal belt. In recent years, with earlier sowing of barley in April in the higher-rainfall southern regions, net-type net blotch has increased to the extent that it threatens the use of susceptible varieties such as Stirling (Gilmour, pers. comm.).

Yield losses to net-type net blotch were investigated by Khan (1987) using a Critical Point Model on data from six environments. Grain yield losses ranged from 4 to 33% and a regression coefficient of 0.37 was produced when assessments were made on the top three leaves at Zadoks Growth Stage 75. This was not significantly different from the regression of 0.32 found by Khan and D'Antuono (1985) when investigating yield loss relationships with scald in Western Australia. They suggested that the two figures could be combined to provide a better fit for both diseases in their environment.

Spot-type net blotch was first recorded in Western Australia in 1977 and is confined to the areas of the cereal belt north of about 29°S. Using an Area Under Curve (AUC) model on 14 field experiments over seven years where disease occurred, Khan (1989) obtained a regression coefficient of 0.023 but found the model only accounted for 60% of the variation in yield. Significant yield losses were found in just four trials and these ranged from 3 to 22%.

In Queensland, net blotch was not reported before 1980. Before then, barley seed was often treated with mercurial seed dressings, barley crops were isolated in rotations and stubble was regularly burnt. These practices would have been effective in suppressing net blotch. More recently, net-type net blotch has been severe in some very early and late sown commercial crops and where sprinkler irrigation has been used. Clipper and Grimmett have provided useful resistance, but net blotch was conspicuous in Grimmett in 1992 and a change in virulence may have occurred (Rees, pers. comm.). With greater popularity of reduced-tillage farming the disease is expected to become more important.

In south-eastern Australia, net blotch used to be severe in some barleys in some seasons. The release of resistant Clipper in 1968 led to a dramatic reduction in the incidence of the disease. Net blotch is now rarely seen in this region. This is probably due to a combination of plant resistance, a less-than-ideal climate for the disease and the use of effective seed treatment. In New South Wales, barley is usually only grown one year in six or less often, so there is little opportunity for any carryover of inoculum from one crop to the next.

Whereas in New Zealand control of net blotch has come almost entirely from the use of seed treatments, in Western Australia seed treatments have been less effective because triadimenol, which is not effective against net blotch, is widely used for scald and powdery mildew control and imazalil is considered too expensive to be combined with triadimenol or other products. Seed treatments such as carboxin may have played a significant role in suppressing the disease in some lower-rainfall areas of Australia where scald and powdery mildew are less of a problem. Resistant varieties have therefore played a more significant role in controlling net blotch in Australia than in New Zealand. The combination of stubble retention in farming systems and dry summers preventing breakdown of infected stubble has meant that crop rotation has also been an important means of reducing disease in crops.

Screening and breeding

In Western Australia, field nurseries are used each year to screen the top 300 breeding lines and parent lines for resistance to both types of net blotch. Exotic introductions are used in the breeding program to improve malting quality, parents are screened for their level of resistance to both diseases with the objective of rejecting those that are highly susceptible. Little selection is otherwise made for resistance to spot-type net blotch as the disease is not considered a high priority.

In Queensland, glasshouse screening has been conducted regularly at Toowoomba and field screening was planned to start in 1993. Resistant material and differentials were recently

obtained from Canada and will be used to improve the resistance in the Queensland program.

In New Zealand, screening is carried out in field nurseries at Palmerston North. A research project at Lincoln aims to transfer net blotch resistance into barley from *H. bulbosum* (Pickering et al. 1987).

There is currently no specific breeding program for net blotch resistance in Australia.

Barley stripe

Barley stripe is not a disease of any significance in Australia or New Zealand. It has not been seen for many years in South Australia or Victoria and has only been seen in commercial crops from imported untreated seed in Queensland, New South Wales and New Zealand. In these states it has been controlled by chemical seed treatments.

In Western Australia barley stripe had not been seen for two decades until 1987. The disease had previously been controlled by organo-mercurials and carboxin. Its reappearance at three sites in that season appears to have been due to the susceptibility of cv Forrest on which it was found, and to the use of ineffective triadimenol seed treatment. In field trials conducted using contaminated cv Forrest, Khan and Loughman (1988), and Loughman and Khan (1993) found triadimenol provided little control of the disease but that carboxin, flutriafol and imazalil were effective.

No screening or selection for resistance occurs in Australia or New Zealand.

Spot blotch

Spot blotch is favored by more humid sub-tropical climates, so it is mostly found in the lowland areas of central Queensland. In these areas, barley growing is fairly limited so little work has been done on the disease. In 1983, a number of barley crops on the eastern, more humid, side of the dividing range in Queensland were devastated, and yield losses of up to 70% were recorded (Rees, pers. comm.). In New Zealand, the disease is common on North Island where it can cause significant yield losses (Cromey, pers. comm.).

Crop rotation and stubble management are recommended for control and a new emphasis on breeding for resistance has been suggested (Rees, pers comm.). Rees (pers. comm.) has also detected specificity in the *Cochliobolus* population, so breeding may not be straightforward.

Ring spot

Ring spot is caused by the fungus *Pyrenophora semeniperda* (Shoemaker 1966), which is common across southern Australia. The disease causes small, 1–2 mm diameter, dark brown rings with tan centers on the leaves of all cereal and most grass crops. Ring spot rarely causes damage to crops although extensive leaf damage has occurred in young crops in South Australia (Wallwork, unpublished) and Western Australia (Loughman, pers. comm.) where inoculum carryover was high on infected grass stubble.

Wirrega blotch

Wirrega blotch was first recorded in 1990 in South Australia and described as *Drechslera wirreganensis* (Wallwork et al. 1992a). The disease caused yield losses of up to 30% in susceptible varieties in one naturally infected trial (Wallwork and Potter, unpublished), but has not yet caused yield losses in commercial crops. This pathogen is taxonomically related to ring spot and is found in two forms, a blotch form and a spot form. The latter produces a ring spot lesion similar to *P. semeniperda* although a hole is usually found in the leaf. The pathogen appears to infect a wide range of grass species similar to the situation with *P. semeniperda* (Wallwork, unpublished)

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Barley Disease Incidence in Tunisia

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Abstract

Surveys for barley (*Hordeum vulgare* L. subsp. *vulgare*) diseases in the different agro-ecological zones of Tunisia showed large differences between years in the occurrence and intensity of the different diseases. Leaf blights were especially severe in the more humid coastal areas, but scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) was also severe in the cooler areas of the Central region.

Key words: *Hordeum vulgare*; barley; blights; scald; *Rhynchosporium secalis*; plant diseases; morbidity; Tunisia.

Introduction

Barley is a major cereal crop in Tunisia. However, the yield level is low, and overall production varies with the prevailing climatic conditions. Self-sufficiency and stable barley production may be achieved if losses from biotic and abiotic stress are reduced and appropriate cultural practices are applied.

Method

Annual disease surveys were conducted in Tunisia in 1990–92 and the incidence of various barley diseases has been established. Over the three-year period, 212 barley fields were surveyed:

(1) 23 fields in the North Eastern region (Governorates of Tunis, Ben Arous and Zaghouan);
(2) 40 fields in the North Western region (Governorates of Kef, Jendouba and Seliana);
(3) 90 fields in Central Tunisia (Governorates of Kasserine, Gafsa and Sidi Bouzid);
(4) 14 fields in the Oasis (Governorates of Tozeur, Nefta and Kebilli);
(5) 10 fields in the southern region (Governorates of Mednine and Zarzis);
(6) 35 fields in the East Coast region (Governorates of Gabes, Sfax and Sousse).

الإصابة بأمراض الشعير في تونس

الملخص

أظهرت الدراسات الحصرية عن أمراض الشعير (*Hordeum vulgare* L. subsp.*vulgare*) في المناطق البيئية – الزراعية المختلفة من تونس أن ثمة فروقات كبيرة بين السنوات في حدوث الإصابة وشدتها بمختلف الأمراض. فقد كانت أمراض لفحة الأوراق شديدة على نحو خاص في المناطق الساحلية الأكثر رطوبة، إلا أن السفحة (*Rhynchosporium secalis* (Oud.) J.J.Davis) كانت شديدة أيضاً في البقاع الأبرد من المنطقة الوسطى.

Results

Powdery mildew (*Erysiphe graminis* DC. ex Mérat f.sp. *hordei* Em.Marchal [= *Oidium monilioides* Desm.]), net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]), barley stripe (*Pyrenophora graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]), and scald were the most common diseases (Table 1).

In the North Eastern region, net blotch and powdery mildew were the most prevalent diseases. Scald and covered smut (*Ustilago hordei* (Pers.) Lagerh.) occurred at high incidence in 1991. In 1992, leaf rust (*Puccinia hordei* Otth) incidence was high (43%).

In the North Western region, powdery mildew and scald were the predominant diseases, followed by net blotch. The incidence of barley stripe, covered smut, barley yellow dwarf and barley free-state viruses was also high (25 to 50%).

In the Central region, powdery mildew, barley stripe and net blotch were the most prevalent diseases. Covered smut, leaf rust, stem rust (*Puccinia graminis* Pers. f.sp. *tritici* Eriks. & E.Henn.), barley yellow dwarf and barley free-state viruses were encountered in several fields in 1991. Root rots (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem.]) and scald were more common in 1992; their relative incidence was 32% and 41%, respectively.

In the Oasis and the Southern regions, the disease incidence varied from year to year. Powdery mildew showed the highest incidence followed by barley stripe. Stem rust, leaf rust and root rots were observed in 1991. Scald was not encountered.

In the Eastern Coastal region, net blotch and powdery mildew had higher incidence than the other diseases in 1991.

Table 1. Barley disease incidence in Tunisia, 1990–1992.

Region	NT	NB		Sc		BSt		PM		Sm		LR		RR	
		N	I	N	I	N	I	N	I	N	I	N	I	N	I
N. East	23	18	8.5	5	2.3	2	0.9	13	6	5	2.3	1	0.5	3	1.4
N. West	40	21	10	25	12	19	9	29	14	9	4	3	1.4	2	0.9
Central	90	44	21	30	14	48	23	74	35	24	11	9	4.2	21	10
Oasis	14	3	1.5	0	0	4	2	5	2	3	1.4	2	0.9	2	0.9
South	10	4	2	0	0	2	0.9	8	4	1	0.5	4	1.8	1	0.5
Coast	35	24	11	7	3.3	8	4	23	11	14	7	8	3.7	6	2.8
Total	212	114		67		83		152		56		24		35	

NT = No. fields surveyed; NB = net blotch; Sc = scald; BSt = barley stripe; PM = powdery mildew; Sm = covered smut; LR = leaf rust; RR = root rots; N = no. infected fields; I = disease incidence (%).

Discussion

The surveys conducted in Tunisia during 1990–92 show that powdery mildew had a high incidence across the major barley-growing areas of Tunisia; net blotch is more common in North Eastern and Coastal regions; barley stripe has its highest incidence in the Central region; and scald is more predominant in the North Western and Central regions. The incidence of other diseases should not be ignored, but carefully monitored. The seed-borne diseases (barley stripe and loose smut [*Ustilago nuda* (Jens.) Rostr.]) are particularly prevalent in fields where farmers use their own (untreated) seed.

The impact of these diseases on yield and production could be minimized if improved resistant genotypes could be developed. Success in breeding for disease-resistant cultivars would greatly enhance barley production.

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Importance and Control of Barley Leaf Blights in Ethiopia

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Abstract

Barley (*Hordeum vulgare* L. subsp. *vulgare*) is one of the principal cereal crops in Ethiopia. On average, 800,000 tonnes are produced from 0.8 million hectares. Research on barley diseases started in 1970 with the establishment of the Institute of Agricultural Research (IAR). Scald, leaf blotches and rusts are the most important diseases. Crop loss studies on *Rhynchosporium secalis* (Oud.) J.J.Davis and *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem., Syn. *Helminthosporium teres* Sacc.) showed yield

أهمية امراض لفحة الأوراق على الشعير ومكافحتها في إثيوبيا

الملخص

يعتبر الشعير *(Hordeum vulgare* L. subsp. *vulgare)* من محاصيل الحبوب الرئيسية في إثيوبيا. ويبلغ متوسط الإنتاج 800,000 طن من مساحة قدرها 0.8 مليون هكتار. وقد بدأت الأبحاث على أمراض الشعير في 1970 مع إقامة مركز البحوث الزراعية (IAR). ومن أهم تلك الأمراض، السفحة وتبقع الأوراق والأصداء. أظهرت الدراسات على *Rhynchosporium secalis* (Oud.) J.J. Davis و *Pyrenophora teres* Drechs (=*Drechlera teres* (Sacc.) Shoem. Syn. *Helminthosporium teres* Sacc.) خسارة في الغلة نسبتها 21-67% وحوالي 34% على التوالي. وإن استخدام المقاومة الوراثية يعتبر من أكثر

losses of 21–67 and about 34%, respectively. The use of genetic resistance is the most economical means of barley disease control. During the past 16 years over 6000 lines/cultivars have been tested for resistance to the most economically important diseases – scald (*R. secalis*), net blotch (*P. teres*), spot blotch (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast. [= *Bipolaris sorokiniana* (Sacc.) Shoem., Syn. *Helminthosporium sativum* Pammel, King & Bakke]) and leaf rust (*Puccinia hordei* Otth). Between 1988 and 1989, over 500 lines were tested for resistance to scald. Sixteen were identified and further tested in different locations in 1990. Among these, three were resistant (HB 114, HB 116 and HB 124) and promoted to yield trials. In addition, eight resistant lines identified are used in the crossing program. All but three of these lines were local crosses containing at least one Ethiopian parent.

Of 900 landrace lines tested from 45 populations, representing three locations, five lines were resistant to scald and four to net blotch. These lines are currently in the crossing program.

Experiments were conducted to identify lines with field resistance (slow scalding) to scald in 16 cultivars at four locations. Among these, three cultivars were high yielders possessing slow scalding. One is already in production and the remaining are proposed for commercial production. Another four cultivars also showed field resistance to scald, but were low yielding.

Variability of *R. secalis* was examined in the field using standard differentials at various locations. Infection varied among locations and seasons.

Key words: *Hordeum vulgare*; barley; varieties; selection; disease resistance; *Pyrenophora teres*; *Rhynchosporium secalis*; *Puccinia hordei*; *Cochliobolus sativus*; Ethiopia.

الوسائل اقتصادية في مكافحة أمراض الشعير. وخلال الـ 16 سنة الماضية، تم اختبار مايزيد على 6000 سلالة/صنف لمقاومة أكثر الأمراض أهمية اقتصادية وهي : السفحة (*R. secalis*)، التبقع الشبكي(*P. teres*)، التبقع الهلمنثورسبوري (*Cochliobolus sativus* (Ito & Kurib.) Drechs. ex Dast [=*Bipolaris sorokiniana* (Sacc.) Shoem. Syn. *Helminthosporium sativum* Pammel, King & Bakkel]) وصدأ الأوراق (*Puccinia hordei* Otth). وفيما بين 1988 و1989، تم اختبار مايزيد على 500 سلالة لمقاومة السفحة، حُددت 16 منها لإجراء مزيد من الاختبارات عليها في مواقع مختلفة في 1990. ومن بينها كانت ثلاث مقاومة (HB 114, HB 116 و HB 124)، تم رفعها إلى تجارب مقارنة الغلة، فضلاً عن استخدام ثماني سلالات مقاومة أخرى في برنامج التهجين. وكانت جميع هذه السلالات باستثناء ثلاث منها هجن محلية تحتوي على أب إثيوبي واحد كحد أدنى.

ومن أصل 900 سلالة محلية من 45 عشيرة، مختبرة وممثلة لثلاثة مواقع، كانت خمس سلالات مقاومة للسفحة وأربع للتبقع الشبكي. وهذه السلالات موجودة حالياً في برنامج التهجين. أجريت بعض التجارب لتحديد سلالات ذات مقاومة حقلية (التسفح البطيء) للسفحة على 16 صنفاً في أربعة مواقع، وكانت ثلاثة أصناف منها مغلالة وتتمتع بصفة التسفح البطيء. وإن أحدها قيد الإنتاج حالياً، ويُقترح الباقي للإنتاج التجاري. كما أظهرت أربعة أصناف اخرى مقاومة حقلية للسفحة إلا أنها كانت متدنية الغلة.

تمت دراسة تفاوت *R. secalis* في الحقل باستخدام مجموعة تفريقية قياسية في مواقع مختلفة، فتبين أن الإصابة تختلف حسب المواقع والمواسم.

Introduction

Barley is the third most important cereal crop in Ethiopia (Table 1). In 1988/89, over 1 million tonnes were produced from 0.96 million hectares. In most of the highlands, the crop is cultivated twice a year (Table 2). The June to September rains provide moisture for main-season barley. The February or March to April showers are used for the cultivation of *Belg*-season barley. The consequent lack of sufficient crop-free period enhances the production of abundant disease inoculum.

Most barley in Ethiopia is highly heterogeneous landraces (Endeshaw 1983; Mulugeta 1985). Landraces have coexisted with pathogens in an equilibrium for a long time, which may be the reason that severe epiphytotics are rarely reported on barley in Ethiopia.

Research on barley diseases started in 1971, mainly with the establishment of the Institute of Agricultural Research (IAR). In this paper emphasis is given to work carried out on *R. secalis* and "*Helminthosporium*" spp.

Survey and Identification

About 26 fungi, 1 bacterium, 2 viruses and 7 nematodes are reported on barley (Eshetu 1985). Among these scald, net blotch, spot blotch and leaf rust are the most widely distributed. However, observations on disease incidence and severity were rarely quantified.

Surveys conducted between 1980 and 1983 to determine the distribution and importance of the three "*Helminthosporium*"

Table 1. Area, production and yields of cereals in Ethiopia, 1988/89.†

Crop	Area (1000 ha)	Yield (1000 t)	Production (t/ha)
Teff	1461.2	1277.72	0.83
Maize	1021.1	1688.69	1.65
Barley	958.5	1018.16	1.06
Wheat	647.6	799.94	1.24
Sorghum	627.1	849.21	1.35
Millet	132.9	112.19	0.84
Oat	42.3	47.66	1.13
Total cereals	4890.2	5733.57	1.17
Total	5742.4	6375.81	1.11

† Excludes Assab, Ogaden and Tigray regions.
Souce: Central Statistical Authority (1990).

Table 2. Area, production of cereals by season in Ethiopia, 1988/89.†

Crop	Area (1000 ha)		Production (1000 t)	
	Main	*Belg*	Main	*Belg*
Teff	1341.5	119.8	1185.52	32.20
Maize	808.4	212.7	1544.20	144.49
Barley	651.2	307.3	747.81	270.35
Wheat	595.4	52.2	766.33	33.60
Sorghum	606.4	20.7	838.95	10.26
Millet	129.3	3.6	106.99	5.19
Oat	27.0	15.3	30.63	17.06
Total cereals	4159.2	730.9	5220.43	513.16
Total	4986.5	755.8	5851.14	524.67

† Excludes Assab, Ogaden and Tigray regions.
Souce: Central Statistical Authority (1990).

leaf diseases showed that spot blotch was the most widely distributed disease of barley in the Arsi, Bale and Shewa regions (IAR 1985a, b). Although net blotch had limited distribution, it was severe. However, more recent work has shown that net blotch was the most widely distributed and important disease of barley in the Arsi and Bale regions (Yitbarek 1990).

Surveys to quantify barley diseases were initiated some years ago for the major barley-growing centers. In the central highlands, scald was the major disease, followed by net blotch and leaf rust (Table 3). Of 101 fields sampled between 1989 and 1991, scald was observed in 75 with mean incidence and severity of 59% and 30%, respectively. Similar work in the North Western regions showed that scald followed by spot blotch and net blotch were the most important diseases of barley (Table 4). Although not quantitatively assessed, net blotch, scald, leaf rust and stripe rust were major diseases of barley in the Bale region (IAR 1990a).

Severity of scald showed considerable variation between seasons in the central region (Table 5). Similarly, both the incidence and severity of net blotch and leaf rust showed considerable variation between seasons. The incidence and severity of scald was more important at the research center than on farmers' fields, while the other diseases showed considerable variation.

Table 3. Barley diseases observed during 1989–91 crop seasons in Shewa administrative region.

Disease	No. of fields infected	Mean incidence (%)	Mean severity (%)
Scald	75	59	30
Net blotch	57	67	26
Leaf rust	48	67	20
Spot blotch	17	53	6
Barley stripe	10	9	–
Loose smut	3	14	–
Covered smut	32	0.7	–
Septoria	3	2.4	0.9
Eye spot	1	0.1	0.03

Table 4. Mean disease incidence and severity at heading of barley in North Western region of Ethiopia during 1990 crop season.

Disease	Mean incidence (%)	Mean severity (%)
Scald	58.9	16.0
Net blotch	29.5	5.0
Spot blotch	47.1	14.1
Leaf rust	8.4	4.9
Barley stripe	7.7	
Covered smut	7.0	
Loose smut	5.4	

Source: IAR (1992a).

An attempt was made to determine the relationship of some environmental factors with the incidence and severity of these diseases (Table 6). Scald was significantly influenced by topography and number of tillers, while net blotch was affected by topography, field size and growth stage. However, this was not conclusive since fields and sampling time differed among years, and cultivars/cultural practices and survey personnel differed among locations. The lack of correlation between scald and altitude could be associated with the narrow differences in altitude between locations within the region.

Variability in the pathogen population of *R. secalis* was assessed using differentials in the field in 1990 and 1992 (Table 7). Variability existed among locations as well as among seasons. All the differentials except Osiris showed least infection toward the end of the season at Holetta, while few remained immune at other locations. This suggests a wide range of virulence in the pathogen population, which could be associated with differences in disease pressure among regions.

Loss assessments

Some disease epiphytotics on barley are more important in causing serious losses, because of the growing environment of the crop (high rainfall, cool and humid environments), the persistence of inoculum almost throughout the year, and the occurrence of more pathogenic agents.

Studies on yield loss of barley due to some important fungal agents have been carried out since 1978. Among pathogenic agents, *R. secalis* caused a yield reduction of 21–67% for different seasons and cultivars (Table 8). *Pyrenophora teres* caused up to 34% loss.

Table 5. Variation among seasons and locations of the incidence and severity of some important diseases of barley.

Year	Scald		Net blotch		Leaf rust	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
1989	68	31 b†	67 b	20 a	66 b	19 ab
1990	43	50 c	91 ab	68 b	89 b	27 b
1991	50	17 a	53 a	10 a	33 a	6 a
Location‡						
1	54 a	27 a	71 a	34 a	68 a	16 a
2	55 a	32 a	67 a	17 a	68 a	26 a
3	75 a	36 a	40 a	10 a	52 a	80 a
4	100 b	55 b	60 a	10 a	50 a	5 a

† Means followed by the same letter within a column are not significantly different (P=0.05) as determined by LSD.
‡ Locations: 1. Route between Holetta and Gohatsion; 2. Route between Holetta and Gedo/Woliso; 3. Route between Holetta and Debresina; 4. Holetta Research Center.

Table 6. Correlation between some environmental factors and incidence and severity of some important diseases observed between 1989 and 1991.

Year	Scald		Net blotch		Leaf rust	
	Incidence	Severity	Incidence	Severity	Incidence	Severity
Altitude	0.10	-0.04	-0.09	0.13	-0.02	-0.08
Topography	0.01	-0.20*	-0.20	-0.24*	-0.22	-0.20
Drainage	-0.003	0.03	-0.21	-0.15	0.04	0.12
Field size	0.14	0.07	-0.31*	-0.18	0.03	-0.04
Growth stage	0.01	0.11	0.43**	-0.47**	-0.003	-0.24
No. plants/m²	-0.20*	-0.39**	0.001	-0.17	-0.14	0.01

Table 7. Incidence of scald on barley differentials during 1990 and 1992 crop seasons.†

Differential	1990				1992		
	Holetta	Adet	Injibera	Bekoji	Holetta	Adet	Injibara
Gebrel	0	0	5	51	11	0	2
Pirate	42	10	4	51	13	0	35
Tipper	31	5	5	42	22	2	20
Pipkin	21	2	10	43	32	0	10
Astrix	52	5	6	41	21	3	10
Athene	0	4	4	41	21	1	5
Igri	0	2	0	0	21	0	0
Hoppel	0	5	3	0	11	1	40
Osiris	0	0	0	0	11	0	0
Digger	62	20	30	61	95	5	3
Maris Mink	85	30	35	76	88	30	35
La Mesita	88	25	30	89	98	10	50
Armella	88	10	8	67	88	35	40
Trebi	88	30	35	72	94	20	40
Jet	84	20	15	61	94	5	20
Kitchin	84	25	20	51	96	10	30
Steudelli	99	35	4	72	98	2	30
Bay	88	30	10	97	88	2	25
Atlas 46	88	25	5	98	97	5	20
Modac	87	20	20	82	85	4	50
Forrajera	72	45	5	0	64	15	30
Nijrinudum	85	15	10	62	84	4	30
Turk	51	10	5	73	21	0	10
Ardu-12-8C (check)	99	30	35	88	98	20	50
HB 42	0	0	0	0	21	0	0
Ardu-12-60B	52	0	0	0	11	0	20
Proctor	88	30	45	78	94	40	60

† Disease rating at Holetta and Bekoji was on 0-9 double digit, but at Adet and Injibara was on infection percentage.
Sources: IAR (1991b, 1992b).

Table 8. Yield losses due to some important pathogens of barley.

Pathogen	Loss (%)	Reference(s)
Rhynchosporium secalis	21–67	IAR (1970, 1972, 1983, 1985b)
Pyrenophora teres	21–34	Yitbarek and Dereje (1985)
Pseudocercosporella herpotrichoides (Fron) Deighton	0.63–8.5	Eshetu and Yitbarek (1983)
Puccinia hordei	2.4–14.2†	IAR (1972, 1985b)
Puccinia striiformis West.	0–21.8†	IAR (1971, 1972)

† Not conclusive because of interference by other leaf diseases

Control of Barley Diseases

Cultural practices

Experiments were conducted to control scald around Holetta by using various planting dates. Planting of a susceptible cultivar on 12 and 15 June resulted in high scald and yield losses of 31 and 43%, respectively (IAR 1971, 1972). Minimum losses were observed in plots planted on 27 to 30 June.

Use of resistant/tolerant cultivars

The use of genetic resistance is by far the most economical, efficient, environmentally acceptable and long-term sustainable means of controlling barley diseases.

Over 6000 cultivars were screened for scald, blotches, rusts, smut and foot diseases between 1970 to 1986, mainly under field conditions (Eshetu 1985).

Resistance to *R. secalis* of over 500 lines/cultivars and populations was evaluated in the field between 1988 and 1990 (Yitbarek and Brehane 1996). Initial tests were done at Holetta and promising lines were further tested at seven other locations. Of these, three lines (HB 114, HB 115 and HB 116) were resistant and agronomically acceptable, and therefore proposed for yield tests. The lines 22/82-9H-S-2-2-OH, EH 621/F_2-2H-3-3-2-1P-OH, EH 623/F_2-4H-28-9-6W-OH and EH 623/F_2-4H-28-9-6P-OH were resistant to *R. secalis* but agronomically poor, so are recommended as parents for the crossing program. A further four lines with low scald but poor agronomic characters were also recommended for crossing program.

Emphasis was given to the use of local landraces as sources of resistance. A set of 900 pure lines originating from 60 landrace populations were tested for scald and net blotch at three locations (Yitbarek, Fekadu and Berhanu, pers. comm.). Of these, five lines (1745-7, 1745-13, 3390-0, 3336-12 and 3336-20) were resistant to scald, and four lines (3336-3, 3336-5, 333-6 and 333-20) were resistant to scald and net blotch. In addition, lines with low scald and net blotch and good agronomic characters are being evaluated in multilocation yield tests. A further 21 lines are being tested for slow scalding and another 20 lines for tolerance to scald.

To identify scald-tolerant lines, 30 cultivars were tested in three experiments at Holetta for three seasons (IAR 1990b, 1991a; Yitbarek and Dereje 1985). Each cultivar was planted in pair treatments where one part was protected by repeated fungicide application. Comparison was made on disease progress and yield. Results led to the identification of EH/538/F_2-12-6-2, EH 270B/F_2-4B-11-95H-3, Beka, Ardu-12-8C, EH 270B/F_2-4B-11-5B-5, EH 537B/F_2-11-6 and HB 7 as tolerant lines.

Sixteen cultivars of barley were evaluated for field resistance to *R. secalis* for three consecutive seasons at Holetta and for one or two seasons at three other locations (Yitbarek in press). HB 42, HB 99 and HB 100 showed least disease progress during the season and highest yield. The first is currently in commercial production and the others are proposed for commercial use. In addition, cultivars Ardu-12-60B, Holkr and Balkr also showed lower disease progress, although their yields were not high; these were released for commercial production some years ago.

Chemical control

Effect of fungicides on economically important diseases has been studied since the early 1970s. Etem (maneb) reduced the incidence of scald on cultivar Firlbecks (IAR 1971). Incidence of scald was significantly reduced with 8 sprays of maneb with a yield advantage of over 80%. In subsequent studies, repeated application of tridemorph (Calixin) at 0.1% and benomyl (Benlate) at 0.03% a.i. reduced scald and other "*Helminthosporium*" leaf diseases (IAR 1977). In addition, application of these fungicides in combination with seed treatments (Benlate 50 at 2.5 g/kg and Agrosan [sodium chlorate] at 2.0 g/kg) were also better than the untreated checks.

As a follow-up exercise, some new fungicides and the previously recommended fungicides were tested against scald and blotches (IAR 1985a, b). Generally, the new fungicides were superior to those previously recommended in controlling the disease. Severity of scald was significantly reduced by the application of propiconazole (Tilt 250EC), triadimefon (Bayleton) and chlorothalonil (Bravo 500). However, there was no significant increase in yield in any of the treatments. This was probably associated with low disease pressure due to dry weather, especially during the last two years of the experiment. A similar result was also obtained in the control of net blotch. Application of flutriafol (Impact) resulted in about 17% increase in yield of *Cochliobolus sativus* infected plots.

Experiments in barley production fields also showed that net blotch could be controlled with the application of propiconazol (Tilt 250EC) and prochloraz (Sportak 45%EC). These were recommended for use in production fields where net blotch is a problem (Terefe 1990).

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Field Evaluation of Barley for Resistance to Scald in Ethiopia

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Abstract

The objective of this study was to identify barley (*Hordeum vulgare* L. subsp. *vulgare*) line(s) combining resistance to *Rhynchosporium secalis* (Oud.) J.J.Davis with high yield potential and good agronomic characteristics, that can be used directly or as a source of resistance. Entries of different origin were evaluated in the field at Holetta during 1988 and 1989. Of 519 lines tested, 16 were resistant and were tested at 7 locations during in 1990.

Four genotypes were immune to scald at all locations. Based on scald resistance, high yield and good agronomic characters, HB 114, HB 115 and HB 116 were selected for multilocation yield tests. Sixteen lines from the USDA world barley collection reportedly resistant to highly virulent Californian scald strains were also tested at the same 7 locations in 1990. All except one line were susceptible.

Key words: *Hordeum vulgare*; barley; selection; varieties; disease resistance; *Rhynchosporium secalis*; yields; Ethiopia.

Introduction

Barley is a traditional crop in the highlands of Ethiopia grown over a wide range of climates (Central Statistics Authority 1987). Two crops per year are commonly produced in most barley-growing regions. The lack of sufficiently long crop-free period results in an abundance of inoculum for most barley diseases.

Scald, caused by *Rhynchosporium secalis*, is the most widely distributed and destructive disease of barley in Ethiopia (Eshetu 1985). The disease is most commonly observed in highlands (above 2300 m) where precipitation is high and temperature is low during the cropping period. Yield losses up to 67% occur on susceptible cultivars during disease-favorable seasons (IAR 1970). Generally, heavy epidemics are associated with early planting of the crop.

The importance of scald in Ethiopia was recognized some years back, so the disease has received major emphasis in variety development programs (Fekadu 1987). Most of the current improved varieties have acceptable levels of resistance. However, continuous evaluation of the available germplasm is essential for identifying sources of resistance and for coping with this highly variable pathogen. The purpose of the present study was to identify lines that combine a high level of resistance to *R. secalis* with agronomic qualities that can be used immediately, or that can be used as sources of resistance in breeding programs.

Material and Methods

Three groups of germplasm were tested in 1988 and 1989 seasons at Holetta Research Center. In the first season, 25 breeding lines from the national barley breeding program at Holetta and 65 lines selected from different international sources were tested. In the second season, 313 randomly selected Ethiopian barley landraces collected from different growing areas (obtained from the Plant Genetic Resources Center, PGRC/E), 27 breeding lines from the breeding program at Holetta and 89 lines from international sources were tested. Selected genotypes from these tests were further tested at seven locations in 1990, together with 16 accessions from the USDA

التقييم الحقلي لمقاومة الشعير للسفحة في إثيوبيا

الملخص

تهدف هذه الدراسة إلى تحديد سلالات الشعير *(Hordeum vulgare* L. subsp.*vulgare)* التي تجمع بين المقاومة لـ *Rhynchosporium secalis* (Oud.) J.J.Davis والكفاءة الإنتاجية العالية والصفات الزراعية الجيدة. إذ يمكن لتلك السلالات أن تستخدم مباشرة أو كمصدر للمقاومة. تم تقييم مدخلات مختلفة المنشأ في الحقل في هوليتا خلال 1988 و1989. ومن أصل 519 سلالة مختبرة، كانت 16 مقاومة، وقد تم اختبارها في 7 مواقع خلال 1990.

تمتعت أربعة طرز وراثية بمناعة ضد مرض السفحة في جميع المواقع. وبناءً على صفة مقاومة السفحة، أنتخبت HB 114، HB 115 و HB 116 المغلالة والجيدة الصفات الزراعية بهدف إجراء اختبارات مقارنة الغلة المتعددة المواقع عليها. كما تم اختبار 16 سلالة من مجموعة الشعير العالمية التابعة لوزارة الزراعة الأمريكية، والتي ذُكِر أنها مقاومة لسلالات السفحة الكاليفورنية ذات الفوعية الشديدة، في المواقع السبعة نفسها في 1990. وكانت جميع السلالات حساسة باستثناء واحدة.

collection. The 16 USDA accessions were Ethiopian landraces collected in 1970 by Wiese which possessed high levels of resistance in field tests in California (Webster et al. 1980).

In all the tests, each entry was planted in a plot of two rows, 1.0 m long and 0.2 m apart. A susceptible cultivar, Ardu-12-8C, was planted in three rows adjacent to each plot as disease spreader. At Holetta, scald-infected stubble collected from the previous season and stored at room temperature (18–25°C) was distributed when seedlings were at the 3–5 leaf stage to supplement the natural infection, while at the other locations the screening relied entirely on natural infection.

Disease development was rated using a 0–9 double-digit scale, where the first digit refers vertical development (relative height) of the disease (0 = no disease, 5 = disease half-way up the plant, and 9 = disease spread to the head), and the second refers to leaf area affected (≤ 10%=0, 10–20%=1, etc.) (Saari and Prescott 1975). Leaf area affected (second digit) of the last reading was used to categorize each group of germplasm: 0–1 = resistant (R), 2–3 = moderately resistant (MR), 4–5 = moderately susceptible (MS), 6–7 = susceptible (S), and 8–9 = very susceptible (VS). At Holetta, disease was recorded every 7–10 days. The first, middle and last record are reported here. One record at heading was taken in other locations.

Results and Discussion

Among the 313 PGRC/E accessions tested, only two were resistant and more than 80% were either susceptible or very susceptible at Holetta. These accessions were landraces that are possibly composed of genotypes with different levels of resistance. Attempts were not made to identify individual plants, so the performance of more resistant components in the population could have been masked by the generally poor performance of the population. Current studies on selections from Ethiopian landraces show that it is possible to identify pure lines with resistance to the disease (Yitbarek, Fekadu and Berhane, unpublished data).

Of 154 lines from international sources tested during 1988 and 1989, only one was resistant and more than 80% were very susceptible to the disease. In contrast, about 29% of the Ethiopian breeding lines showed resistance during the same period.

Disease assessment showed that scald was highest at Holetta followed by Adet, Injibara and Mota. The use of infected stubble, early planting and the favorable environment at Holetta resulted in heavy epidemics of scald in each year of testing. First scald symptoms were generally observed 4–5 weeks after planting and recording started at 6–8 weeks when the disease was uniformly distributed in the field. Little scald was observed at Asasa and Sheno, probably because of adverse temperature during July and August. Little scald developed at Bekoji (normally a hot-spot) due to heavy infestation by net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc.) Shoem.]), another important barley disease in the area.

Among the lines obtained from the breeding program at Holetta, 22/81-9H-S-2-2-OH, EH 621/F_2-2H-3-3-2-1P-OH, EH 623/F_2-4H-28-9-6W-OH and EH 623/F_2-4H-28-9-6P-OH were immune to *R. secalis* at all locations (Table 1). Cultivars HB 114, HB 116 and HB 124 had low scald at most of the locations. Some infection was observed on EH 764/F_2-65H, EH 764/F_2-75, EH 774/F_2 -75H and HB 115 at more than one location. Lines 22/81-9H-S-2-2-OH, IBON 73/86, EH 764/F_2-65H, EH 764/F_2-75H and EH 764/F_2-85H were obtained from international nurseries and others were local crosses with at least one Ethiopian parent (Table 2). Of the many introductions, few proved resistant in our situation. On the other hand, a good number of lines developed locally were resistant to the disease. Based on their higher yield, scald resistance and good agronomic characters, lines HB 114, HB 115 and HB 116 were advanced to multilocation yield tests. Lines 22/81-9H-S-2-2-OH, EH 621/F_2-2H-3-3-2-1P-OH, EH 623/F_2-4H-28-9-OH and EH 623/F_2-4H-28-9-6P-OH were not good yielders although they showed good scald resistance. These are being retained as sources of scald resistance.

Observations on Ethiopian-originated barley populations of the USDA collections showed that all except PI 386731 were highly susceptible at Holetta (Table 3). PI 382946, PI 386908, PI 386966 and PI 387117 had little or no infection in more than one site. Susceptibility of these lines, which were highly resistant in California (Webster et al. 1980), could be attributed to the variations in virulence and composition of the pathogen population in these geographically distinct regions.

Lines resistant at all locations probably posses resistance to most of the virulences of the Ethiopian scald population and could be used until their resistance is countered by new pathotypes of the pathogen.

Acknowledgement

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Table 1. Scald rating† at seven locations in Ethiopia of barley lines previously selected for resistance to *Rhynchosporium secalis*, 1990.

Line no.‡	Holetta			Adet§	Asasa	Bekoji	Injibara§	Mota§	Sheno
	14 Aug	4 Sep	24 Sep						
1	00	00	00	0	00	00	0	0	00
2	00	00	00	0	00	00	0	0	00
3	00	00	00	0	00	00	0	0	00
4	00	00	00	0	00	00	0	0	00
5	41	84	87	15	00	00	0	1	21
6	00	00	00	25	00	00	15	1	00
7	00	00	00	15	00	00	30	1	00
8	00	00	41	25	00	00	45	0	00
9	00	82	83	30	00	00	50	5	00
10	00	00	00	15	00	00	25	10	00
11	00	21	51	25	00	00	25	20	00
12	00	52	62	35	00	00	30	15	00
13	00	00	00	0	00	00	1	0	00
14	00	00	51	5	tr	51	5	0	00
15	00	00	00	0	00	00	5	0	00
16	00	00	00	10	00	00	10	0	00
Ardu-12-8C (Susc. check)	52	86	99	58	tr	97	55	45	31

† Scored on a 0–9 double digit: first digit for vertical development (0 = no disease, 5 = half way up plant, 9 = to head); second digit for leaf area affected (≤10% = 0, 10–20% = 1, 20–30% = 2, ..., 90–100% = 9), tr = trace.
‡ See Table 2 for pedigree and parentage.
§ Disease scored based on percentage of whole plant.

Table 2. Pedigree and parentage of barley lines resistant to scald at Holetta in 1988 or 1989.

No.	Pedigree	Parentage
1.	22/81-9H-S-2-2-OH	F_2 bulk (S × W) CIMMYT
2.	EH 621/F_2-2H-3-3-2-1P-OH	Ahor 880/61 × (Comp. 29 × Bedi Black 6R)
3.	EH 623/F_2-4H-28-9-6W-OH	IAR/H/485 × Ahor 880/61
4.	EH 623/F_2-4H-28-9-6P-OH	IAR/H/485 × Ahor 880/61
5.	IBON 73/86	ORE"S" 1133/BATMIM10/3/Sel 9 AULA DEI/4/383059 CM882-1374-A 24-1B-14-Om
6.	EH 764/F_2-65H	(CI 4375.1A × C 63) × (CI 4375.1A × Comp. 29)
7.	EH 764/F_2-75H	(CI 4375.1A × C 63) × (CI 4375.1A × Comp. 29)
8.	EH 764/F_2-85H	(CI 4375.1A × C 63) × (CI 4375.1A × Comp. 29)
9.	EH 774/F_2-65H	(Kenya Research × Hol. M. Sel. 10) × (CI 4375.1A × C 63)
10.	EH 774/F_2-75H	(Kenya Research × Hol. M. Sel. 10) × (CI 4375.1A × C 63)
11.	EH 774/F_2-95H	(Kenya Research × Hol. M. Sel. 10) × (CI 4375.1A × C 63)
12.	EH 774/F_2-85H	(Kenya Research × Hol. M. Sel. 10) × (CI 4375.1A × C 63)
13.	EH 621/F_2-2H-9-4-2-OH (HB 114)	Ahor 880/61 × (Comp.29 × Bedi Black 6R)
14.	EH 621/F_2-2H-135-3W-OH (HB 115)	Ahor 880/61 × (Comp.29 × Bedi Black 6R)
15.	EH 621/F_2-2H-13-5-3P-OH (HB 116)	Ahor 880/61 × (Comp.29 × Bedi Black 6R)
16.	EH 663/F_2-27H-20-14-OH (HB 124)	(Kenya Research × Trabout) × Beka

Table 3. Scald rating† at seven loations in Ethiopia of 16 barley populations previously reported to be resistant in California.

Population	Holetta			Adet‡	Asasa	Bekoji	Injibara‡	Mota‡	Sheno
	14 Aug	4 Sep	24 Sep						
PI 382368	41	62	85	45	00	61	65	25	21
PI 382375	42	85	88	50	21	62	35	35	62
PI 382523	21	84	88	35	00	41	40	30	31
PI 382946	21	41	62	0	00	00	5	0	00
PI 383069	41	85	88	25	00	00	30	45	41
PI 383181	21	72	86	25	00	71	25	20	00
PI 385629	31	42	62	35	tr	00	25	40	41
PI 386731	00	31	42	25	00	41	20	10	00
PI 386770	21	61	86	30	00	51	30	20	00
PI 386771	41	62	85	10	00	00	10	15	00
PI 386825	41	62	86	85	00	00	50	30	00
PI 386880	41	84	86	80	00	61	70	20	41
PI 386908	31	62	85	10	00	00	5	0	00
PI 386966	00	31	83	5	00	51	1	5	00
PI 387096	00	85	99	70	tr	96	70	25	86
PI 387117	00	21	72	50	00	00	1	25	00

† Scored on a 0–9 double digit: first digit for vertical development (0 = no disease, 5 = half way up plant, 9 = to head); second digit for leaf area affected (≤10% = 0, 10–20% = 1, 20–30% = 2, ..., 90–100% = 9).

‡ Disease score based on percentage of whole plant.

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Abstracts of Posters

Resistance to *Rhynchosporium secalis* of Advanced Breeding Lines and Pure Line Selections of Barley Landraces

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Advanced breeding lines and landraces of barley (*Hordeum vulgare* L. subsp. *vulgare*) from Syria, Jordan, Egypt and Algeria were tested for resistance to *Rhynchosporium secalis* (Oud.) J.J.Davis in the field in Syria, using local pathogen strains. Resistant lines were present in all five groups of germplasm, but the largest proportion of resistance was found in the breeding material and the landraces from Syria and Algeria. Among resistant and moderately resistant lines, 90 lines were selected for further testing at the Welsh Plant Breeding Station. Pathogen races with specific virulence were used for both field tests and seedling tests in the greenhouse. Nearly all lines retained their resistance in the field test, but no correlation between field test and seedling test was present.

Search for Antagonists of the Resting Forms of *Drechslera teres*, the Causal Agent of Barley Net Blotch

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Since the early 1980s net blotch of barley (*Hordeum vulgare* L. subsp. *vulgare*), caused by *Drechslera teres* (Sacc.) Shoem. (= *Pyrenophora teres* Drechs.), has become epidemic in France. *In-vitro* and *in-vivo* biological control of this fungus has used of antagonistic organisms or hypo-aggressive strains. The pathogen can differentiate into multiple resting forms on crop residues. Preliminary investigations, within the framework of the biological control of the disease, were aimed at searching for and isolating micro-organisms that are able to restrict and/or prevent the appearance of the pathogen resting forms on barley straw. Ten micro-organisms obtained from a screening carried out on little or non-infected barley straw were able to prevent or inhibit the formation of sclerotioid organs. However, these micro-organisms had no curative effect. The mycelium obtained from the germination of sclerotioid organs previously treated with antagonists was less virulent to barley seedlings.

Distribution and Characteristics of Bacterial Leaf Streak of Barley (*Xanthomonas campestris* pv. *hordei*) in Iran

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Bacterial leaf streak of barley (*Hordeum vulgare* L. subsp. *vulgare*) was observed in the southeastern, central and western regions of Iran, the disease was even present in the irrigated barley fields of the driest province (Yazd). The symptoms (translucent streaks) were limited to the foliage. Many strains of the bacterium were isolated in different areas. All strains were bacteriologically similar to *Xanthomonas campestris*. They hydrolyzed gelatin, casein, aesculin, Tween 80, Tween 60, Tween 20 and lecithin, but not arginin.

They produced SH_2 from pepton and cystein, and acids from sucrose, glucose, galactose, fructose, cellobiose, mannose, trehalose, D-arabinose, L-arabinose, D-xylose, glycerol, levulose, α- and β-lactose, but not from melibiose, maltose, mannitol, adonitol, sorbitol, raffinose, rhamnose, dextrin, salicin, inositol, meso-inositol, dulcitol, L-xylose, ethanol, methanol, or butanol. They utilized acetate, citrate, succinate, fumarate, lactate, malate, malonate, and propionate, but not benzoate, formate, oxalate or tartrate. Typical symptoms were observed on barley but not on other inoculated plants including wheat, oat, rye, *Agropyron* sp. and *Lolium* sp. From their bacteriological characteristics and host range, the strains were identified as *Xanthomonas campestris* pv. *hordei*.

Improvement of Barley Genetic Resistance to *Pyrenophora teres* by Hybridization and Mutagenesis

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Isolates of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.) f.sp. *maculata* Smedegaard-Petersen and *P. teres* f.sp. *teres* were collected in 1986 and 1987 from fields in various regions of France. Variation in pathogenicity was evaluated using 12 barley (*Hordeum vulgare* L. subsp. *vulgare*) cultivars. Arrivate and 79S10-10 cultivars were resistant to all isolates except R5 and S5. The Ethiopian line CI-5791, previously reported to be resistant, was susceptible to the R5 and S5 biotypes. There was a strong correlation between the classification of cultivars for resistance to *P. teres* f.sp. *teres* and *P. teres* f.sp. *maculata*. A new method for conserving the virulence of the isolates on straw was evaluated. The virulence level of the isolates was the same after four years of storage using this method. We developed an agar leaf-disk technique to determine *P. teres* resistance in barley. The results were correlated with the seedling and adult plants (r = 0.90–096). Both tests and leaf-disk technique were used to determine *P. teres* resistance in reciprocal crosses among nine barley genotypes. Diallel analysis showed significant general and specific combining abilities (GCA, SCA), whereas maternal effect was not significant. GCA and SCA were determined for yield, protein content, 1000-grain weight, protein yield, and non-protein yield for both healthy and *P. teres* diseased plants. High genetic variability for the traits was observed. Non-protein yield and 1000-grain weight decreased significantly in inoculated plants, whereas protein yield was not affected. Values for GCA and SCA for some traits were significantly modified by *P. teres*.

Barley seeds of two cultivars (Smash and Thibaut) and one line (74-F-6) with water contents adjusted to between 12.8 and 13.3%, were irradiated with various doses (1–160 Gy) of ^{60}Co gamma rays. Doses of 15 and 20 Gy decreased barley susceptibility to *P. teres* f.sp. *maculata* by 25 and 21%, respectively. This reduction was a function of the line or cultivar used. The best response was obtained with cv Smash. Seedling growth stimulation and host susceptibility to *P. teres* were significantly correlated (r = 0.68). The stimulatory effect of gamma rays on growth could be used at low levels to provide adequate field resistance to net blotch caused by *P. teres* f.sp. *maculata*. Selection was done in M_2 population for resistance to this pathogen and M_4 tolerant mutants presenting several modified agronomic characters were tested. Doubled haploids (DH) were produced and used as a rapid production of recombinant barley lines resistant to *P. teres*. Several DH lines were selected and their genetic gain was evaluated.

Detection of *Pyrenophora teres* using Allele Specific Oligonucleotides (ASO)

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Polymerase Chain Reaction (PCR) protocols were developed for the detection of the net and spot forms of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.). Low copy number sequences selected from a *P. teres* f.sp. *maculata* Smedegaard-Petersen random genomic library were used as a source of probes. Emphasis was placed on those sequences identifying DNA polymorphisms between net and spot isolates and with little or no sequence similarity with barley (*Hordeum vulgare* L. subsp. *vulgare*), wheat

(*Triticum* spp.) or triticale (×*Triticosecale* Wittm. ex A.Camus) genomes. Sequences identifying a large deletion in genomic DNAs of net and spot isolates were preferred over sequences detecting small DNA changes. Sequence data of the probe pPtm-290 was used to construct allele-specific oligonucleotides to amplify the corresponding sequence in genomic DNAs of net and spot isolates present in barley plants infected with these pathogens. All the PCR experiments conducted with the oligonucleotides designated as Pt-1 and Pt-2 showed a high association between the presence of a 430 bp band and the presence of the pathogen in genomic DNAs of barley infected with the net form, spot form, or both pathogens. PCR offers a sensitive, rapid, and non-radioactive technique for the detection of *P. teres* infection in field-grown barley plants. Future experiments should focus on the detection of *P. teres* and *P. graminea* S.Ito & Kuribay. in infected barley seeds. If this is achieved, PCR-based protocols for *P. teres* and *P. graminea* detection could possibly be incorporated into seed certification programs to avoid the distribution of infected seed in farmers' fields.

DNA Probe to Fingerprint Species within the Genus *Pyrenophora*

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A 731-bp genomic DNA fragment was cloned from *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.) f.sp. *maculata* Smedegaard-Petersen, the causal agent of spot blotch disease of barley (*Hordeum vulgare* L. subsp. *vulgare*). Under the conditions of this study, restriction enzymes *Bst EII*, *Hind III*, *Eco RI*, and *Bam HI* produced RFLP patterns that discriminated *Pyrenophora* species. The grouping of the *Pyrenophora* species according to unique banding patterns led to much the same delineation as classical taxonomic procedures. The exceptions were *P. graminea* and the two forms of *P. teres*. *Pyrenophora graminea* S.Ito & Kuribay. (= *Drechslera graminea* (Rab.) Shoem.) had slight homology to pPtm-290; *P. teres* f.sp. *maculata* and *P. teres* f.sp. *teres* each showed a consistent banding pattern that was unique for each form. Ribosomal DNA from *Neurospora crassa* was also useful for determining taxonomic characters of *P. teres*. The polymorphisms in rDNA restriction lengths and those observed with pPtm-290 indicate that the two forms of *P. teres* could be considered as separate species within the genus *Pyrenophora*. The RFLP patterns produced by the DNA probe pPtm-290 for each particular species provides a powerful tool for fingerprinting species within *Pyrenophora*.

Virulence Spectrum to Barley in Some Isolates of *Pyrenophora teres*

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The pathogenicity of 61 Tunisian and 11 Maghrebin (from Morocco, Algeria and Libya) single-spore isolates of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.), the causal organism of net blotch of barley (*Hordeum vulgare* L. subsp. *vulgare*), collected in 1990 and 1991 was evaluated using 12 barley differential cultivars. Of these isolates, 71% were of the net form, *P. teres* f.sp. *teres*, and 29% were of the spot form, *P. teres* f.sp. *maculata* Smedegaard-Petersen. On the basis of reaction type (0–4 scale) four pathogenicity groups (highly virulent, virulent, intermediate and avirulent) were recognized. Their frequency was of 16.7, 55.5, 26.4 and 1.4%, respectively. The frequency of virulence was higher for Tunisian isolates than for the other isolates. The most virulent Tunisian isolates were collected from the north of the country. Among the Maghrebin isolates, Marchouch's was the most virulent. There was some variation in pathogenicity among single-spore isolates from the same location. A highly differential reaction between isolates and cultivars was observed. The cultivar Martin was the most susceptible of all cultivars, but it was not susceptible to all isolates. Similarly, 82 RPT 45, the most resistant cultivar, was not highly resistant to all isolates.

Transgressive Segregation and Race Non-specific Resistance to Net Blotch in Barley

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Two crosses among four fairly susceptible barley cultivars (*Hordeum vulgare* L. subsp. *vulgare*) were tested in F_1, F_2, and the selected resistant F_3, F_4, F_5 and F_6 generations at seedling stage for their resistance to a different Maghrebin isolates of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.). A linear decrease of infection type (0B4 scale) as well as a linear increase in percentage resistant plants (infection type less than 3) from F_1 to F_6 was shown. In each generation, infection type was reduced by 0.3 and percentage of resistant plants was improved by 10. Seven diverse isolates of *P. teres* were used to screen the F_5 lines in the seedling stage. Both disease-evaluation methods, infection type and percentage of resistant plants showed that the resistance obtained in the later generations can be race non-specific. The resistance selected seems to be durable.

Thionins and Thaumatin-like Proteins in Barley–*Pyrenophora graminea* Interaction

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The resistance response of barley (*Hordeum vulgare* L. subsp. *vulgare*) to *Pyrenophora graminea* S.Ito & Kuribay. (= *Drechslera graminea* (Rab.) Shoem.) is a complex phenomenon because the biological role of the three known resistance genes is still obscure. Infected plant cells induce a set of genes that may be involved in resistance or susceptibility. In order to identify and monitor the expression of these genes, a molecular experiment was carried out using two isolates (*Dg2* and *Dg5*) of *D. graminea* and the six-rowed barley variety Thibaut. This variety showed resistance to *Dg2* and susceptibility to *Dg5*. From infected roots, mRNAs were extracted and hybridized in a Northern analysis by using 10 molecular probes which corresponded to genes known to be involved in plantBpathogen interaction. The results indicated that thaumatin-like and thionin genes are involved in the response of barley to *D. graminea* infection. The corresponding mRNAs are expressed in the cells of root tips 24 h after the contact between host and pathogen.

Evaluation of Field Resistance of Commercial Barley Cultivars and Advanced Lines to *Rhynchosporium secalis*

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Scald (*Rhynchosporium secalis* (Oud.) J.J.Davis) is one of the most important diseases of barley (*Hordeum vulgare* L. subsp. *vulgare*) in the east of Mazandaran, Iran. Twenty-four cultivars and advanced lines were evaluated for resistance to scald during the years 1990B92. The differences for scald incidence between the years were significant. In 1990 and 1991 scald development was moderate, but in 1992 its intensity had an epidemic character in Gorgan and Gonbad area. In addition, artificial inoculation was made by spraying conidial suspension of fungus isolates. Differences in reaction to scald among cultivars and lines were highly significant.

Most diseased were Arass and Gorgan; Karoon, Eram and Local Barley were less affected. The least affected were cultivars Valfarje, Rihane-03 and C63.

Research on Barley Leaf Blights in Canada

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At present, Canadian research on scald (*Rhynchosporium secalis* (Oud.) J.J.Davis), net blotch (*Pyrenophora teres* Drechs. [= *Drechslera teres* (Sacc) Shoem.]), and leaf stripe (*P. graminea* S.Ito & Kuribay. [= *Drechslera graminea* (Rab.) Shoem.]) of barley (*Hordeum vulgare* L. subsp. *vulgare*) is being done primarily at four Agriculture Canada (AC) research establishments: Lacombe, Alberta; Winnipeg, Manitoba; Ottawa, Ontario; and Charlottetown, Prince Edward Island. The studies in progress fall into the broad categories of etiology and epidemiology, components of resistance, control with seed treatments and/or foliar fungicides, and identification and incorporation of resistance genes. In addition, screening for resistance to one or more of the diseases is being done as part of the barley breeding programs at Lethbridge, Alberta (AC), Saskatoon, Saskatchewan (University of Saskatchewan), Brandon, Manitoba (AC), and Guelph, Ontario (University of Guelph). Graduate studies on scald or net blotch are occasionally undertaken at the above-mentioned universities.

Seed-borne Inoculum of *Pyrenophora teres*, the Causal Agent of Barley Net Blotch

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The investigation of the localization of *Pyrenophora teres* Drechs. (= *Drechslera teres* (Sacc.) Shoem.) in seeds of barley (*Hordeum vulgare* L. subsp. *vulgare* cv Thibaut) showed that when contamination occurred at the time of flowering, all parts of the caryposis, including the embryo, were infected by the two forms (*teres* and *maculata*) of the pathogen. The assessment of the possible role of some abiotic factors resulted in the characterization of the effect of temperature and soil moisture on the expression of the primary symptoms caused by the two forms of the pathogen. The most severe damage was observed in dry soils (pF 3B4) at about 12EC. On young barley seedlings, the seed-borne pathogen was the origin of coleoptilar symptoms in f.sp. *maculata* Smedegaard-Petersen, whereas f.sp. *teres* induced mostly foliar symptoms. Foliar necrosis might result from systemic evolution of the pathogen.

Effect of Scald on Yield and Yield Components of 12 Winter Barley Genotypes

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The effects of scald epidemics, induced by *Rhynchosporium secalis* (Oud.) J.J Davis, on the yield and quality of winter malting barley (*Hordeum vulgare* L. subsp. *vulgare*) have not been reported in the Pacific Northwest region, USA. This investigation assessed yield and quality losses in resistant and susceptible winter barley genotypes in diverse environments of the Pacific Northwest region of the USA. As consistent, uniform infection is required for resistance breeding, three inoculation methods were compared with a fungicide-

protected check. Disease development was poor at one location (Pendleton) and excellent at the second (Corvallis). Yield reductions at Corvallis ranged from 27 to 40%. Resistant genotypes showed lower disease severities and yield losses than susceptible genotypes. Natural infection was as effective in generating epidemics as was infected straw or spore inoculation. Of the yield components, number of spikes per unit area was most affected by scald. There was no consistent effect of disease on grain weight, although kernel plumpness was reduced under disease pressure. Genotype × environment interactions were pronounced. Resistant genotypes were higher yielding than susceptible genotypes under disease pressure. The opposite was true under minimal disease pressure.

Cultural and Pathogenic Variability in *Pyrenophora graminea* Isolates

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Pyrenophora graminea S.Ito & Kuribay. (= *Drechslera graminea* (Rab.) Shoem.) (Syn. *Helminthosporium gramineum* Rabh.), the causal agent of leaf stripe disease of barley (*Hordeum vulgare* L. subsp. *vulgare*), was shown to exhibit cultural and pathogenic variability. Twenty-eight massal isolates of *P. graminea* originally from barley-growing dry areas (Tunisia, Algeria, Morocco, Libya, Syria and Turkey) were studied for their cultural characters (pigmentation, density of mycelium, radial growth, and conidia size). Four cultural groups were distinguished on the basis of growth rate. However, stability of these characters has not been established. The virulence of eight isolates was studied on 15 barley cultivars, both under greenhouse and field conditions to establish a barley differential set. Seed inoculation was made by sandwich method, then seeds were transplanted and disease assessed by means of infection percentage and AUDPC (Area Under Disease Progressive Curve). This latter criterion was used to observe disease progression on the different cultivars. Inoculation tests differentiated five and four virulence groups in the greenhouse and in the field, respectively, and identified cultivars with potential tolerance to the isolates studied. Positive and highly significant correlations occurred between disease in greenhouse and different disease notations in the field, and AUDPC.

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