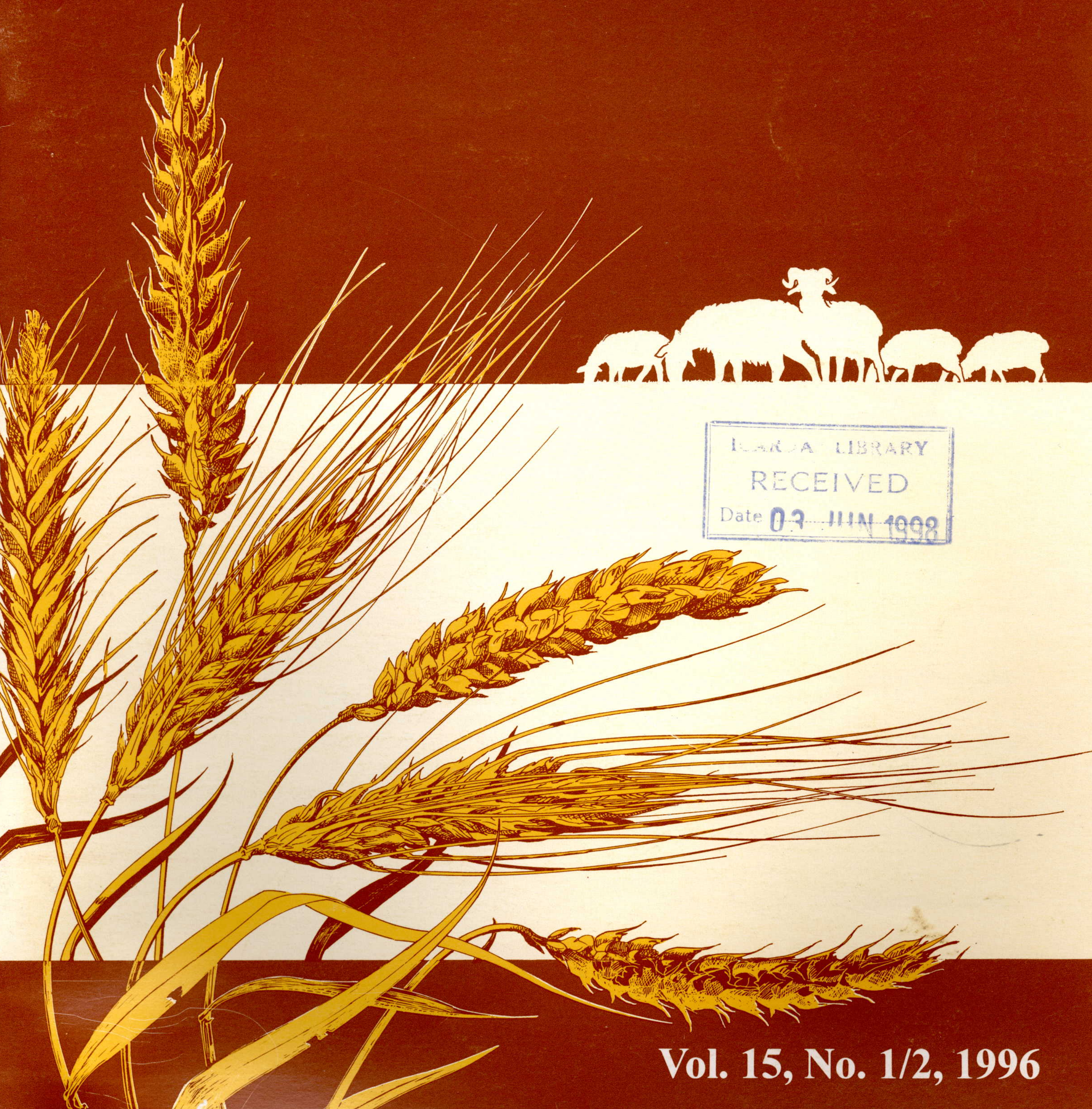
RACHIS

Barley and Wheat Newsletter



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Vol. 15, No. 1/2, 1996

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Research and Production

Evaluation and Characterization of Hull-less Barley Germplasm in Nepal

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Abstract

A total of 1388 hull-less barley (*Hordeum vulgare* L. subsp. *vulgare*) accessions obtained from the USDA gene bank were planted and evaluated during 1990 at Khumaltar Agriculture Research Centre in Lalitpur, Nepal. The plot size was a single row, 1-m long. The important traits studied were days to heading, plant height, yellow rust, lodging, awn characteristics, grain color and grain yield. Mean, range and standard error were calculated for each trait. Coefficients of correlation were also measured between grain yield and other yield-related traits. The 6-rowed barleys constituted 83.5% of the total. They showed greater variation in days to heading, plant height, yellow rust severity and awn characteristics, and were more resistant to lodging. However, the 2-rowed lines were more resistant to yellow rust and higher yielding than the 6-rowed lines. Yellow rust and plant height were the two traits most closely associated with grain yield. Although only 6-rowed types are found in Nepal, the efficient utilization of 2-rowed types with disease resistance would be a feasible approach for increasing and stabilizing barley productivity in Nepal.

Key words: *Hordeum vulgare*; barley; evaluation; germplasm; disease resistance; rusts; heading; height; glumes; lodging resistance; Nepal.

تقييم وتوصيف الأصول الوراثية للشعير العاري في نيبال

الملخص

زُرع وقُيم ما مجموعه 1388 مدخلاً من الشعير العاري (*Hordeum vulgare* L. subsp. *vulgare*)، تم الحصول عليها من البنك الوراثي لدى وزارة الزراعة الأمريكية، خلال 1990 في مركز خومالتار للبحوث الزراعية في لاتيبور بنيبال. وكان حجم القطعة التجريبية خطاً مفرداً طوله متر واحد. وكانت الصفات الهامة المدروسة، هي عدد الأيام حتى الإسبال، طول النبات، الصدأ الأصفر، الرقاد، خصائص السفا، لون الحب، والغلة الحبية. ثم تم حساب متوسط ومدى كل صفة وخطئها المعياري، كما تم قياس معامِلات الارتباط بين الغلة الحبية والصفات المتعلقة بها. وقد شكلت سلالات الشعير السداسية الصف نسبة 83.5% من المجموع، مظهرة تبايناً أكبر في عدد الأيام حتى الإسبال، طول النبات، شدة الإصابة بالصدأ الأصفر وخصائص السفا ومقاومة أكبر للرقاد. غير أن السلالات الثنائية الصف كانت أكثر مقاومة للصدأ الأصفر وأكبر غلة من السلالات السداسية الصف. وكانت الصفتان، الإصابة بالصدأ الأصفر وطول النبات، أكثر الصفات اقتراناً بالغلة الحبية. وعلى الرغم من أنه لايوجد في نيبال سوى طرز سداسية الصف، إلا أن الاستخدام الكفء للطرز الثنائية الصف المقاومة للأمراض سيشكل أسلوباً مجدياً لزيادة إنتاجية الشعير واستقرارها في نيبال.

Introduction

Barley is an important crop in the high hills of Nepal where climatic conditions are harsh. Barley requires fewer heat units to reach physiological maturity than many other cereals (Harlan 1986). It is used as both food and feed. It is also used for making alcoholic beverages particularly in the high hills. Hull-less barley is preferred over the hulled type because it does not need to be dehulled. For many people in the high hills of Nepal, this crop remains a mainstay in their diets (Sherchand et al. 1976). The present study covers 1388 hull-less barley accessions provided by the USDA gene bank. They came from countries extending north to 70°N latitude and as high as 4000 meters above sea level in the Tibetan plateau.

Genetic improvement is achievable only if enough genetic variation exists in the population. It is essential to characterize and assess the genetic material in the environment where it is to be grown. The objective of this study was to characterize and evaluate the 1388 accessions for important agronomic and morphological traits which could be used in barley breeding.

Material and Methods

A total of 1388 hull-less barley accessions were planted in single rows of 1 m length at the Agriculture Research Centre, Khumaltar, Lalitpur, Nepal during autumn 1989. Spacing between rows was 25 cm. Fertilizer was applied at the rate of 45-30-0 N-P-K per hectare. Two light irrigations were provided early in the season. One weeding was done prior to heading stage. Statistical analysis was carried out using MSTAT software. Important morphological and agronomic traits studied were days to heading, plant height, yellow rust infection, lodging, awn length and type, row type, grain color and grain yield.

Results and Discussion

Means and ranges for all studied traits are given in Table 1.

Days to heading

The 6-rowed comprised 83.5% and the 2-rowed 16.5% of the accessions used. About 4% of the accessions did not head, possibly because of sensitivity to photoperiod. The mean and range were 107 days and 86–125 days for the 2-rowed types and 110 days and 82–128 days for the 6-rowed types. More than 53% of the 2-rowed types headed in 100–109 days, but only 31% of the 6-rowed type fell in this class (Fig. 1). On the other hand, over 42% of the 6-rowed types headed in 110–119 days against 29% for the 2-rowed barleys. This suggests that 6-rowed types are mostly late maturing and probably represent broader ecological adaptation.

Plant height

The 6-rowed type presented broader variability in plant height than the 2-rowed type, but with lower mean value. Mean and range were 96 cm and 70–120 cm in the 2-rowed barley and 90 cm and 85–125 cm in the 6-rowed group. The populations of 2-rowed types also had a more symmetrical distribution than the 6-rowed types (Fig. 1). The class 90–99 cm formed 40.4% of the 2-rowed type and 34% of the 6-rowed type, which could be viewed more suitable for high fodder yield in the absence of detrimental factors.

Yellow rust

Yellow rust (*Puccinia striiformis* West.) was scored using the Modified Cob's Scale and was then converted to Coefficient of Infection (COI) (Table 1). The 6-rowed types scored significantly higher mean COI than the 2-rowed types, which suggests that 2-rowed barley lines are more resistant than the 6-rowed lines. Nearly 67% of the 2-rowed types were either totally resistant or showed very low level of infection, whereas only 20.4% of the 6-rowed types fell in this group (Fig. 1). Also, over 21% of the 6-rowed lines were highly susceptible against less than 1% of the 2-rowed lines. The 6-rowed barleys revealed a distinct bimodal distribution pattern, while the 2-rowed types skewed more towards resistance.

Table 1. Means and ranges for agronomic and morphological traits measured in 2-rowed and 6-rowed barley accessions.

Trait	2-row			6-row		
	N	Range	Mean ± SD	N	Range	Mean ± SD
Days to heading	230	86–125	107 ± 6.8	1109	82–128	110 ± 8.6
Plant height (cm)	230	70–120	96 ± 8.5	1087	55–125	90 ± 11.8
Yellow rust (COI)†	230	0–100	14 ± 22	1155	0–100	53 ± 34.8
Lodging score (0–5)‡	230	0–5	1.02 ± 1.3	1158	0–5	0.67 ± 1.1
Awn length score (0–5)§	230	0–5	4.39 ± 1.2	1158	0–5	3.6 ± 1.1
Hoodedness/awnedness¶	230	1–4	3.88 ± 0.4	1158	1–5	3.88 ± 0.7
Grain color††	218	1–6	3.84 ± 1.8	1098	1–6	2.89 ± 1.9
Grain yield	221	10–200	75 ± 32	1108	1–190	47 ± 35

† COI = coefficient of infection.
‡ 0 = none, 1 = 10–20%, 2 = 20–40%, 3 = 40–60%, 4 = 60–80%, 5 = 80–100%.
§ 0 = awnless, 1 = < 1 cm, 2 = 1–5 cm, 3 = 5–10 cm, 4 = 10–15 cm, 5 = 15–20 cm.
¶ 1 = sessile hood, 2 = elevated hood, 3 = awnless, 4 = awns on all, 5 = intermediate.
†† 1 = white, 2 = brown/white, 3 = black/white, 4 = brown, 5 = black/brown, 6 = black.

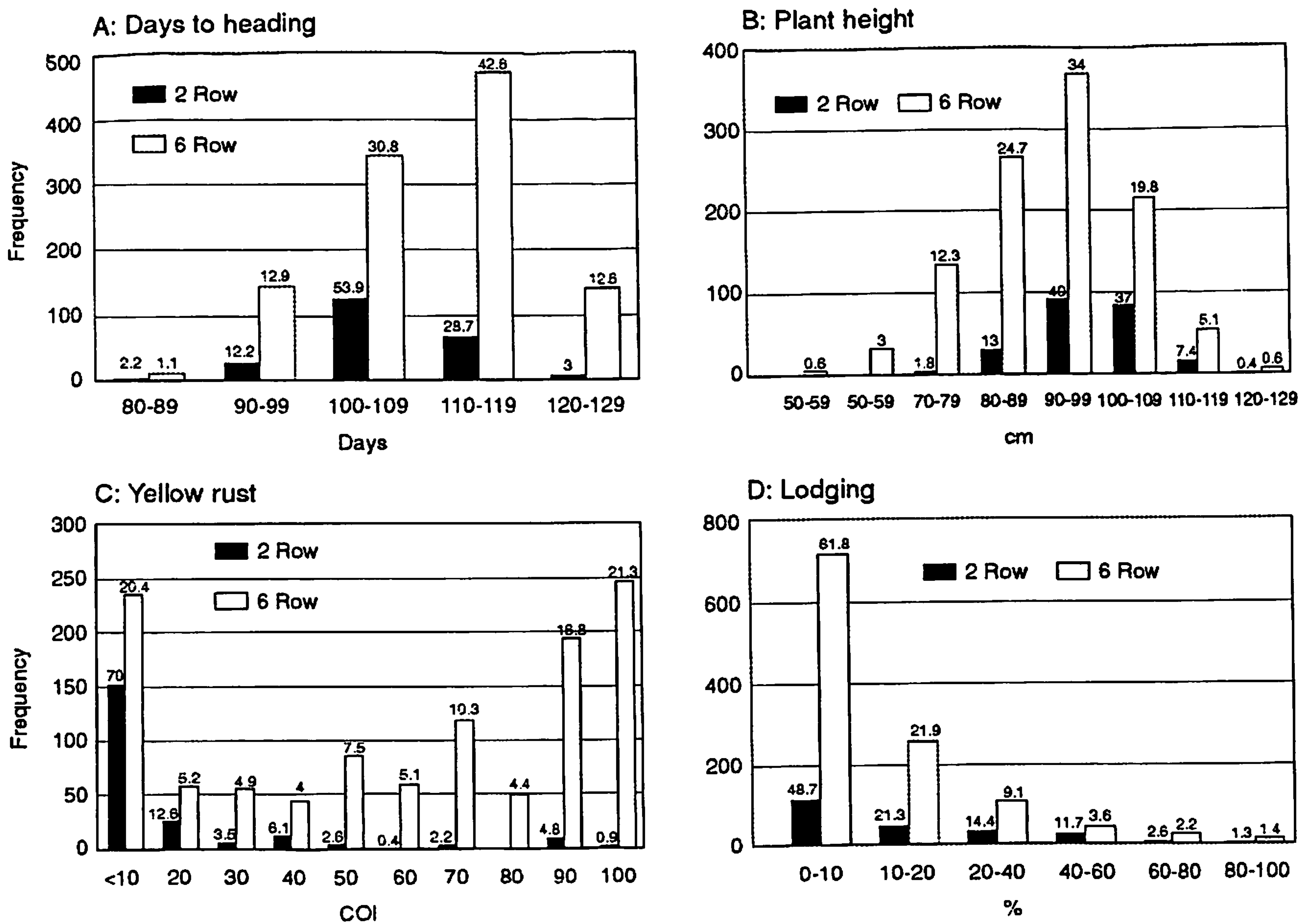

Figure 1. Frequency distribution for 8 traits in 2-rowed and 6-rowed barley accessions.

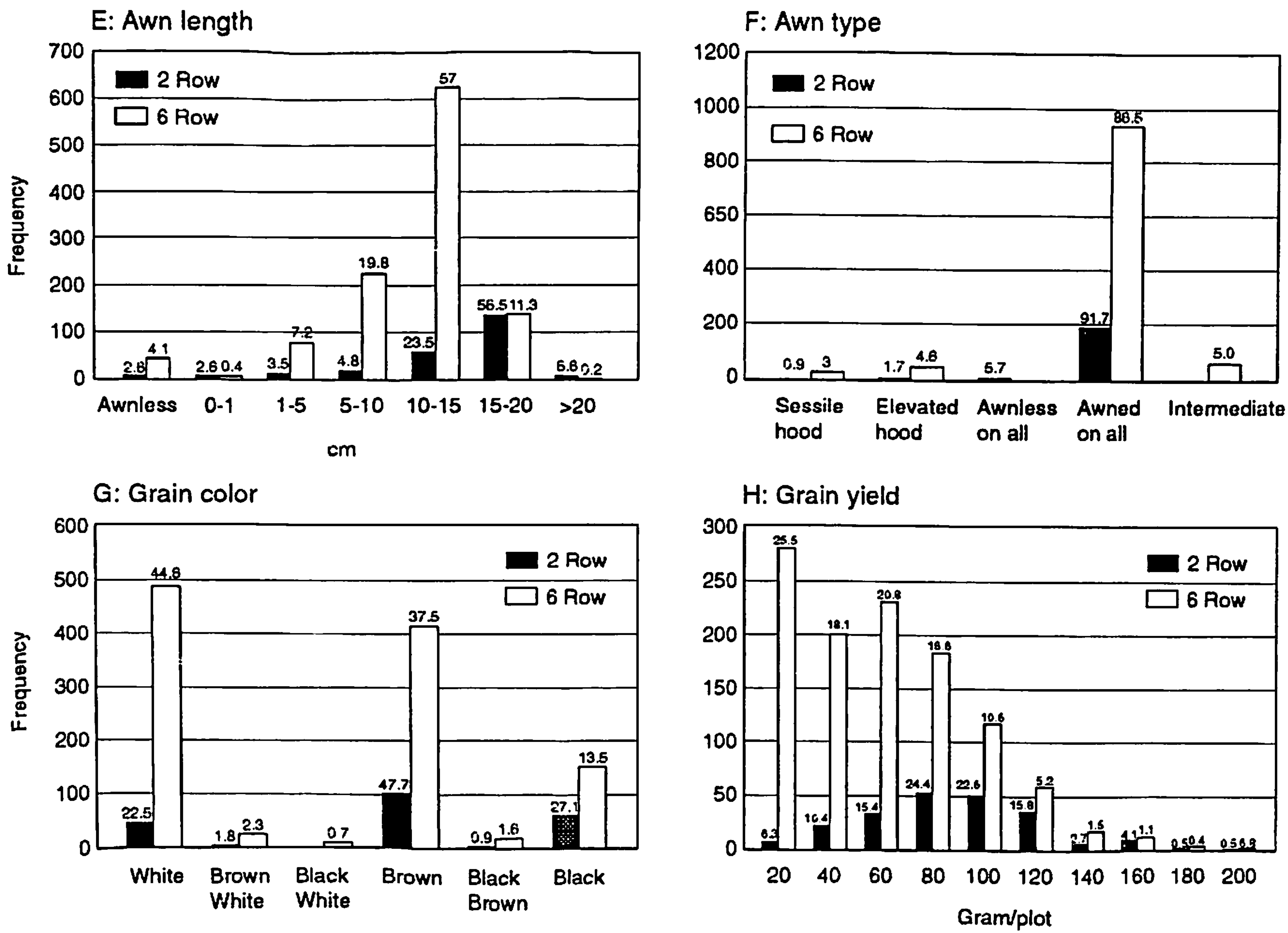

Figure 1. Frequency distribution for 8 traits in 2-rowed and 6-rowed barley accessions (cont.).

Lodging

Lodging is detrimental to grain yield and may be caused by several factors such as weak culm, tall plant, higher disease severity and application of fertilizers. The 6-rowed types had lower average lodging than the 2-rowed types (Table 1). Nearly 48% of the 2-rowed barley and 62% of the 6-rowed barley were non-lodging (Fig. 1). However, higher lodging was not necessarily an indication of poor yield in this study. Lower mean value of plant height and lodging score in the 6-rowed barley indicate that the 6-rowed lines were generally more resistant to lodging than the 2-rowed lines.

Awn length

The awns of 2-rowed barley were generally longer than those of 6-rowed barley. The standard deviation was also greater, suggesting slightly more variation. Over 56% of the 2-rowed lines fell in the 15–20 cm class against only 11.3% of the 6-rowed types (Fig. 1). On the other hand, the 10–15 cm class formed 57% of the 6-rowed barleys and only 23.5% of the 2-rowed barleys.

Hoodedness/Awnedness

In this study, hoodedness/awnedness was characterized based on awn type and its placement. The fourth class—awned on central rows in the 2-rowed barley and on all six rows in the 6-rowed barley—constituted the major portion of both barley types (Fig. 1). Meanwhile, hooded and awnless formed a negligible fraction of the population. Hoodedness is considered undesirable by the growers. The intermediate class, which is the common form of 6-rowed barley grown in Nepal, comprised only 5.8%.

Grain color

Grain color varied from white to black with several intermediate forms. In some cases, grain color varied within accession because of the heterogeneity of the population. This made precise assessment of grain color difficult. Nevertheless, an attempt was made to divide the accessions into six groups, namely, white, brown/white, black/white, brown, black/brown and black. The accessions clustered mainly around the three main colors (white, brown, and black; Fig. 1). White formed 22.5%, brown 47.7% and black 27.1% in the 2-rowed types, and 44.4%, 37.5% and 13.5%, respectively, in the 6-rowed types. The three combination colors made up a small proportion in both types.

Grain yield

Grain yield varied greatly among accessions. Grain from some accessions could hardly be recovered because of severe lodging and yellow rust infection. The average grain yield of the 2-rowed barleys was significantly greater than that of the 6-rowed types. Grain yield of accessions of 2-rowed barley was normally distributed, while that of 6-rowed type was skewed (Fig. 1). Nearly 23% of the 2-rowed barleys had yield higher than 100 g per plot, but only 8.4% of the 6-rowed types did. Although 6-rowed types predominate in Nepalese barley cultivation, the above result suggests that 2-rowed barleys could be introduced successfully.

Correlation among yield and other traits

Coefficients of correlation between grain yield and other traits are given in Table 2. The ultimate goal of evaluating large germplasm pools is to look for higer productivity. Therefore, traits which are closer associated with grain yield would be more important for thorough assessment than others. In this study, the 6-rowed barley showed more stable correlation between grain yield and the traits examined. Grain yield was correlated with taller plant and lower yellow rust infection in both 2-rowed and 6-rowed barleys. Such correlation has been reported previously in barley (Hadjichristodoulou 1987; Samarrai et al. 1987; Gibrel 1990). Grain yield was also positively correlated with more awns per spike, darker lemma and grain color, particularly in the 6-rowed barley, but correlation coefficients were numerically too small to suggest any consistent tend.

Similarly, days to heading was correlated with plant height in the 2-rowed barley, suggesting that taller plants in this group tended to be late heading. Tall accessions were more resistant to yellow rust infection, especially in the 6-rowed types. Although taller plants tended to lodge more, they also gave greater grain yield, and certainly would give higher fodder yield in conditions favoring lodging.

Conclusion

Yellow rust resistance and plant height are probably the two most important factors that contribute to grain yield. Although all the landraces available in Nepal are of the 6-rowed type, this study has indicated that 2-rowed barley could be a valuable source for increasing productivity there. Based on the results of this study, about 76

Table 2. Coefficient of correlation (*r*) among grain yield and other traits measured in 2-rowed and 6-rowed barley accessions.

Character	2-row		6-row	
	N	*r*	N	*r*
Grain yield vs				
Days to heading	221	0.091	1062	0.008
Plant height	221	0.174**	1045	0.188**
Yellow rust (COI)	221	-0.228**	1105	-0.56**
Lodging	221	0.190**	1108	-0.013
Awn length	221	0.10	1108	0.054
Hoodedness/awnedness	221	0.129	1108	0.061*
Grain color	218	0.059	1097	0.198**
Days to 50% heading vs				
Plant height	230	0.27**	1040	-0.018
Yellow rust (COI)	230	-0.007	1107	-0.08**
Lodging	230	0.055	1109	-0.104**
Plant height vs				
Yellow rust (COI)	230	-0.144*	1084	-0.255**
Lodging	230	0.11	1087	0.20**
Yellow rust (COI) vs				
Lodging	230	-0.164*	1155	0.065

*, ** significant at 5% and 1% levels, respectively.

superior lines were selected for further testing and use in breeding.

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Field Evaluation of Barley for Resistance to Scald

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Abstract

A study was conducted to identify barley (*Hordeum vulgare* L. subsp. *vulgare*) lines resistant to *Rhynchosporium secalis* (Oud.) J.J.Davis, with improved yield and agronomic characters, that can be cultivated readily or used as sources of resistance. Five hundred and thirty-five entries of different origins were evaluated in the field at Holetta, Ethiopia during 1988 and 1989. Of these, 16 were resistant; these and 16 populations from the world barley collections of the USDA were further tested at seven locations during in 1990.

Among the 16 lines, four were immune to the disease at all locations. Based on scald resistance, higher yield and agronomic characters, HB 114, HB 115 and HB 116 were selected for multilocation yield tests. Of the 16 populations, all except one were highly susceptible at Holetta, but in other locations two or more populations were resistant to the disease.

Key words: *Hordeum vulgare*; barley; evaluation; varieties; disease resistance; scald; *Rhynchosporium secalis*; Ethiopia.

التقييم الحقلي للشعير لمقاومة السفحة

الملخص

أجريت دراسة لتحديد سلالات الشعير (*Hordeum vulgare* L. subsp. *vulgare*) المقاومة لـ *Rhynchosporium secalis* (Oud.) J.J.Davis ، وذات الغلة والصفات الزراعية الأفضل التي يمكن زراعتها بسهولة أو تستخدم كمصادر للمقاومة. وقد تم تقييم 535 مدخلاً، مختلفة المنشأ، في الحقول في هوليتا بإثيوبيا خلال 1988 و1989، وتبين أن 16 صنفاً منها كانت مقاومة. ثم أُجريت مزيد من الاختبارات على تلك الأصناف وعلى 16 عشيرة من مجموعات الشعير العالمية لدى وزارة الزراعة الأمريكية في سبعة مواقع خلال عام 1990.

ومن أصل الأصناف الستة عشر، كانت أربع حصينة ضد المرض في كل المواقع. وبالاعتماد على مقاومة السفحة، والغلة الأكبر والصفات الزراعية، تم انتخاب الأصناف HB 114، HB 115، وHB116، بغية اختبار غلتها في مواقع متعددة. أما العشائر الست عشرة، فكانت جميعها حساسة بدرجة كبيرة في هوليتا باستثناء واحدة، إلا أنه في مواقع أخرى وجد أن عشيرتين أو أكثر مقاومة للمرض.

Introduction

Barley is a traditional crop in the highlands of Ethiopia, where it is grown over a wide range of climates (CSA 1987). Two crops per year are commonly produced in most barley-growing regions. The lack of a sufficiently long crop-free period sustains the production of inocula for most 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 the highlands where precipitation is high and temperature is cool during the cropping period. Field losses of up to 67% are reported 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 has been recognized for some time, so the disease has received major emphasis in the variety-development programs (Fekadu 1987). Most of the current improved varieties have acceptable levels of resistance. However, in order to identify additional sources of resistance genes and to cope with the highly variable nature of the pathogen, continuous evaluation of the available germplasm is essential. The purpose of this research was to identify line(s) resistant to *R. secalis* and, if possible, with better yield and agronomic qualities, that can be exploited readily or used as source(s) of resistance.

Material and Methods

Five hundred and thirty-five entries—including 313 populations collected from different regions in Ethiopia (obtained from the Plant Genetic Resource Center,

Table 1. Pedigree and parentage of barley lines resistant to scald at Holetta in 1988 or 1989.

Pedigree	Parentage
22/81-9H-S-2-2-OH	F_2 bulk (S × W) CIMMYT
EH 621/F_2-2H-3-3-2-1P-OH	Ahor 880/61 × (Com. 29 × Bedi Black 6R)
EH 623/F_2-4H-28-9-6W-OH	IAR/H/485 × Ahor 880/61
EH 623/F_2-4H-28-9-6P-OH	IAR/H/485 × Ahor 880/61
IBON 73/86	ORE"S" 1133/BATIM10/3/Sel 9 AULA DEI/4/383059 CM882-1374-A 24-1B-14-Om
EH 764/F_2-65H	EH 273B/F_2.3B 21 × EH 269B/ F_2.36B.10.85H.8
EH 764/F_2-75H	EH 273B/F_2.3B 21 × EH 269B/ F_2.36B.10.85H.8
EH 794/F_2-85H	EH 273B/F_2.3B 21 × EH 269B/ F_2.36B.10.85H.8
EH 774/F_2-65H	EH 259 A/F_2.7B.1.15H.1 × EH 273A/F_2.38B.20.11 SH.1
EH 774/F_2-75H	EH 259 A/F_2.7B.1.15H.1 × EH 273A/F_2.38B.20.11 SH.1
EH 774/F_2-95H	EH 259 A/F_2.7B.1.15H.1 × EH 273A/F_2.38B.20.11 SH.1
EH 774/F_2-85H	EH 259 A/F_2.7B.1.15H.1 × EH 273A/F_2.38B.20.11 SH.1
EH 621/F_2-2H-9-4-2-OH (HB 114)	Ahor 880/61 × (Com.29 × Bedi Black 6R)
EH 621/F_2-2H-135-3W-OH (HB 115)	Ahor 880/61 × (Com.29 × Bedi Black 6R)
EH 621/F_2-2H-13-5-3P-OH (HB 116)	Ahor 880/61 × (Com.29 × Bedi Black 6R)
EH 663/F_2-27H-20-14-OH (HB 124)	EH 99/F_3-D.6.14H × Beka

Ethiopia) and 206 lines from the breeding program of Holetta Research Center—were evaluated at Holetta during the 1988 and 1989 seasons. Sixteen entries with acceptable resistance (Table 1) and 16 Ethiopian populations from the world barley collections of the United States Department of Agriculture (USDA) obtained through the International Center for Agricultural Research in the Dry Areas (ICARDA) were further tested during 1990 at seven locations in Ethiopia, to expose the lines to different populations of the pathogen.

In all the tests, each entry was planted in two-row plots, 1 m long and 0.2 m apart. The susceptible cultivar Ardu-12-8c was planted in three rows adjacent to each plot as disease-spreader. At Holetta station, 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 natural infection.

Disease was rated using a 0–9 double-digit scale, where the first digit refers to vertical development of the disease (0 = no disease, 5 = disease spread to half the plant height, and 9 = disease spread up to the spike) and the second digit refers to percentage leaf area affected (0 = disease-free, 1 = up to 10%, 2 = 10–20%, etc.). At Holetta, the disease was recorded every 7–10 days, but only the first, middle and last record are reported here; a single record was taken at heading in other locations.

Results and Discussion

The use of infected stubble, early planting and the favorable environment resulted in heavy epidemics of scald at Holetta. This had been observed over several years, and the site is therefore considered a hot-spot for scald. The disease was first observed about four weeks after planting and developed heavily thereafter, particularly on susceptible cultivars. This situation made it possible for us to screen a large number of entries to identify promising lines for multilocation testing. On the other hand, low disease was observed at Asasa and Sheno stations. This could be due to temperature being too warm (Asasa) and too cool (Sheno) during most of the early growing periods. At Bekoji, another hot-spot for scald, development of the disease was very low because of heavy incidence of net blotch (*Pyrenophora teres* Drechs.), another important barley disease in the area.

Among the 313 local barley populations tested, none showed an acceptable level of resistance at Holetta. These populations are believed to be composed of individuals with different resistances to the disease. Since no attempt was made to identify individual plants, the performance of individual genotypes was masked by the generally poor performance of the population. However, a study on other barley populations showed that after pure-line development it is possible to identify lines with resistance to the disease (Yitbarek, Fekadu and Berhane, unpublished data).

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 2). Lines HB 114, HB 116 and HB 124 had low infection at most of the locations. Some infection was observed on EH 764/F_2-65H, EH 764/F_2-75H, 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 the others mentioned here were derived from local crosses containing at least one Ethiopian parent. 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. Entries 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 not good yielders but exhibited good scald-resistance. These lines have been retained as sources of scald resistance.

Observations on Ethiopia-originated barley populations of the USDA collections showed that, except for PI 386731, all were highly susceptible to scald at Holetta (Table 3). In other locations, PI 382946, PI 386908, PI 386966 and PI 387117 had little or no infection at more than one site. All these populations were reported to posses high levels of resistance to the most virulent iso-

Table 2. Disease rating of barley lines tested for reaction to *Rhynchosporium secalis*.

Line	Holetta†			Adet‡	Asasa†	Bekoji†	Injibara‡	Mota‡	Sheno†
	14/8	4/9	24/9						
22/81-9H-S-2-2-OH	00	00	00	0	00	00	0	0	00
EH 621/F_2-2H-3-3-2-1P-OH	00	00	00	0	00	00	0	0	00
EH 623/F_2-4H-28-9-6W-OH	00	00	00	0	00	00	0	0	00
EH 623/F_2-4H-28-9-6P-OH	00	00	00	0	00	00	0	0	00
IBON 73/86	41	84	87	15	00	00	0	1	21
EH 764/F_2-65H	00	00	00	25	00	00	15	1	00
EH 764/F_2-75H	00	00	00	15	00	00	30	1	00
EH 764/F_2-85H	00	00	41	25	00	00	45	0	00
EH 774/F_2-65H	00	82	83	30	00	00	50	5	00
EH 774/F_2-75H	00	00	00	15	00	00	25	10	00
EH 774/F_2-95H	00	21	51	25	00	00	25	20	00
EH 774/F_2-85H	00	52	62	35	00	00	30	15	00
HB 114	00	00	00	0	00	00	1	0	00
HB 115	00	00	51	5	tr	51	5	0	00
HB 116	00	00	00	0	00	00	5	0	00
HB 124	00	00	00	10	00	00	10	0	00

† Disease rated on 0–9 double-digit scale: first digit refers to vertical development (0 = disease-free, 5 = half-way up plant, 9 = to spike), and second digit refers to severity (0 = disease-free, 1 = up to 10% infection, 2 = 10–20%, etc.).

‡ Disease rating = percentage of whole plants.

tr = trace.

Table 3. Disease rating of barley populations tested for reaction to *Rhynchosporium secalis*.

Population	Holetta†			Adet‡	Asasa†	Bekoji†	Injibara‡	Mota‡	Sheno†
	14/8	4/9	24/9						
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

† Disease rated on 0–9 double-digit scale: first digit refers to vertical development (0 = disease-free, 5 = half-way up plant, 9 = to spike), and second digit refers to severity (0 = disease-free, 1 = up to 10% infection, 2 = 10–20%, etc.).
‡ Disease rating = percentage of whole plants.
tr = trace.

lates of *R. secalis* in California (Webster et al. 1980). These discrepancies could be attributed to the variation in virulence and composition of the pathogen populations in these geographically distinct regions.

This study was limited to the field situation. However, there is a reputation of reliable disease occurrence in locations like Holetta and Bekoji. The other sites used are also known for scald although the disease only occasionally reaches epidemic level. The purpose of testing these lines was to expose them to as wide a variation of the pathogen as possible. Lines which were resistant in all locations probably posses resistance to most of the virulences of the pathogen and could be used before their resistance is overcome by new pathotypes of the pathogen.

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Genetics of Some Spike Characters in Hull-less Barley

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Abstract

Grain threshability in hull-less barley (*Hordeum vulgare* L. subsp. *vulgare*) appears to be controlled by two interacting pairs of dominant non-allelic genes (*Th1Th1, Th2Th2*) with additive effect where free-threshability is only conditioned by two recessive gene pairs (*th1th1, th2th2*); shattering is also controlled by two interacting non-allelic gene pairs with complementary gene effect. Erect vs dropping spike type and 2-rowed vs 6-rowed spikes are monogenically controlled characters where erect (*DD*) is dominant over droopy (*dd*) and 2-rowed (*RR*) is dominant over 6-rowed (*rr*). Therefore these traits could be easily incorporated in the specific hull-less barley background.

Key words: *Hordeum vulgare*; barley; genetics; spikes; abscission; India.

العوامل الوراثية لبعض خصائص السنبلة في الشعير العاري

الملخص

يتحكم في قابلية الحب للدِراس في الشعير العاري (*Hordeum vulgare* L. subsp. *vulgare*)، كما يبدو، زوجان متفاعلان من مورثات سائدة غير أليلية (*Th1Th1, Th2Th2*) ذات أثر متجمع، في حين يتحكم فقط بقابلية الدِراس الحرة زوجان من المورثات المتنحية (*th1th1, th2th2*). كذلك يتحكم في الانفراط زوجان متفاعلان من مورثات غير أليلية ذات تأثير تكميلي. إن طراز السنابل المنتصبة إزاء السنابل المتهدلة والثنائية الصف إزاء السداسية الصف هي صفات يتحكم بها عامل وراثي وحيد، حيث المنتصبة (*DD*) سائدة على المتهدلة (*dd*) وثنائية الصف (*RR*) سائدة على سداسية الصف (*rr*) على التوالي. لذلك يمكن إدخال هذه الخصائص بسهولة في البنية الوراثية الخاصة بالشعير العاري.

Introduction

Barley is considered the first cereal grain used by man. In recent times consumers' preferences have shifted towards other cereal grains such as wheat and rice, not only because of their easy availability but also because of the additional cost and labor imposed by the dehusking of the seed and the low quality of the unleaven bread made of traditional barley. In India, Ram (1985) describes certain grain and spike characters in barley as being important traits to consider in the selection of hull-less barley. The spike traits are free-threshing ability, non-shattering ability, erect habit and six-row heads.

Limited genetic information is available in the literature on the genes controlling some of these characters. This study was undertaken to determine the mode of inheritance of the spike characters in a number of hull-less barley crosses.

Material and Methods

Four contrasting spike characters were chosen for this study: hard-threshability vs free-threshability; shattering vs non-shattering of the grains; erect vs drooping head, and 6-rowed vs 2-rowed heads.

For the first study, four genetic stocks were chosen: EB 65 and Karan-1060 (free-threshing), and AC 2015 (hard-threshing) and K-1140 (semi-hard threshing). For the study of shattering habit, three genetic stocks were chosen: EB 65 and Karan-1060 (non-shattering), and AC 766 (shattering). Shattering of the spike was associated with drooping-head types, therefore four genetic stocks—Karan-15 and Karan-280 (strong erect spike), and EB 65 and Karan-163 (drooping head)—were chosen to study the genetics of these two contrasting traits. Similarly, three genetic stocks—Karan-3 and Karan-16 (6-rowed hull-less) and EB 7576 (2-rowed hull-less)—were chosen to determine the mode of inheritance of the number of rows.

In 1986/87, the following 12 single crosses were made at the Indian Agricultural Research Institute (IARI) Regional Station, Karnal.

1. Hard threshing vs free-threshing:
   AC 2015 (hard) × EB 65 (free).

K 1140 (semi-hard) × EB 65 (free)
AC 2015 (hard) × Karan-1060 (free)
K 1140 (semi-hard) × Karan-1060 (free)

2. Non-shattering vs shattering habit:
   EB 65 (non-shattering) × AC 766 (shattering)
   Karan-1060 (non-shattering) × AC 766 (shattering)

3. Erect vs drooping spike:
   Karan-3 (erect) × EB 65 (drooping)
   Karan-3 (erect) × Karan-163 (drooping)
   Karan-512 (erect) × EB 65 (drooping)
   Karan-512 (erect) × Karan-163 (drooping)

4. 6-rowed vs 2-rowed head:
   Karan-3 (6-rowed) × EB 7576 (2-rowed)
   Karan-16 (6-rowed) × EB 7576 (2-rowed)

The F_1, F_2 and F_3 generations were raised during three consecutive winter seasons (1987/88–1989/90) at IARI-Karnal on irrigated well-fertilized fields. Selection of individual plants was made in the F_2 generation (1988/89) from each cross. Selected F_2 progenies were raised in 1989/90 in plant-progeny rows to confirm the segregation pattern of the F_2 generation.

Chi-squared values were calculated using F_2 and F_3 data to test the goodness of fit of the observed genetic ratios to the expected values.

Results and Discussion

Threshability

The genetic analysis (Table 1) indicated that free-threshability appears to be a digenic character. Two genes (*Th1, Th2*) when present in the homozygous recessive condition (*th1th1th2th2*) confer "free-threshing," while the two corresponding dominant alleles confer "hard threshing" when present in homozygous (*Th1Th1Th2Th2*) or in heterozygous (*Th1th1Th2Th2*; *Th1Th1Th2th2*, *Th1th1Th2th2*) condition. The interaction of these two unlinked genes is thus additive and the presence of both gene pairs in homozygous or heterozygous condition is essential for complete hard-threshability. The presence of a single dominant gene in homozygous (*Th1Th1th2th2* or *th1th1Th2Th2*) or in heterozygous (*Th1th1th2th2*; *th1th1Th2th2*) condition make the threshability semi-hard. Plants with such genetic constitution yield grains with attached husk.

It was further observed that free-threshability of the grain was closely associated with the round grain and thin husk, while "hard-threshing" grains were elongated and had a thick husk. In round grains, the lemma and palea forming the husk open after maturity, which induces free-threshability, while in the hard-threshing types, the elongated grains remain closed in the lemma and palea (husk). Therefore, the spikes selected for the threshability studies were regrouped into round vs elongated grain; thin (or soft) vs thick (or hard) husk; and round grain with thin husk vs elongated grain with thick husk. A genetic analysis was made on these groups. Round vs elongated grain and thin vs thick husk separately segregated into 3:1 ratios in the F_2 generation implying that these are monogenically controlled characters where elongated grain (*LL*) is dominant over round grain (*ll*), and thick husk (*HH*) is dominant over thin (*hh*). When the two pairs of traits are taken together, i.e. round grain with thin husk grain (*llhh*) vs elongated grain with thick husk (*LLHH*), F_2 gave a good fit to a 9:6:1 hard:semi-hard:free-threshing ratio indicating that these are digenically controled. When both genes are dominant, either in the homozygous (*LLHH*) or heterozygous (*LLHh, LlHH, LlHh*) conditions, the grains are elongated and the husks are thick, resulting in hard-threshing grains. When only one gene is dominant (*LLhh, llHH, Llhh, llHh*) the grains are semi-hard threshing. Where both gene pairs are in the homozygous recessive form (*llhh*), the grains are free-threshing. Thus, the two non-allelic unlinked gene pairs *LL* and *HH* function as epistatic to each other. The behavior of F_3 progeny (data not shown) also supports the results obtained in the F_2 generation.

Kitano (1960), Reinberges and Huntley (1957) and Nilan (1964) also report that husking and semi-dehusking are heritable characters, where the semi-naked grain character is controled by a single recessive gene and husklessness was completely epistatic to semi-naked. Similarly, Kushibuchi et al. (1957) report a high association between round (broad) grains and easy husking; narrow grains were more difficult to husk.

Shattering

Shattering appears digenically controled (Table 1) where shattering (*Sh1Sh1Sh2Sh2*) is dominant over non-shattering (*sh1sh1sh2sh2*) in the F_1 generation. *In* F_2, *the* trait segregated into a 9:7 ratio. This indicated that two non-

Table 1. Mode of inheritance of spike characters in F_2 generation of two single crosses in hull-less barley.

Cross	F_1 Behavior	F_2 Behavior	Probable genetic ratio	χ^2 value	P
Hard vs free threshability					
AC2015 × EB65	Hard	134 hard: 81 semi-hard: 13 free	9:6:1	0.604	0.70–0.80
AC2015 × Karan 1060	Hard	168 hard: 115 semi-hard: 15 free	9:6:1	0.800	0.50–0.70
Semi-hard vs free-treshability					
Karan 1140 × EB65	Semi-hard	238 semi-hard: 72 free	3:1	0.520	0.30–0.50
K1140 × Karan 1060	Semi-hard	258 semi-hard: 76 free	3:1	0.328	0.50–0.70
Round vs elongated grain					
Karan 1060 × AC2015	Elongated	120 elongated: 38 round	3:1	0.0759	0.70–0.80
Karan 1060 × K1140 (oval)	Oval	116 oval: 34 round	3:1	0.4355	0.30–0.50
Hard vs soft husk					
AC2015 (hard) × Karan 1060 (soft)	Hard	124 hard: 38 soft	3:1	0.2057	0.50–0.70
K1140 (semi-hard) × Karan 1060 (soft)	Semi-hard	112 semi-hard: 33 soft	3:1	0.1111	0.70–0.80
Round soft husk vs elongated hard husk					
Karan 1060 (round soft) × AC2015 (elongated hard)	Elongated hard	138 elongated hard: 83 oval semi-hard: 14 round soft	9:6:1	0.8753	0.30–0.50
Karan 1060 (round soft) × K1140 (oval semi-hard)	Oval semi-hard	180 oval semi-hard: 56 round soft	3:1	0.2033	0.50–0.70
EB65 (round soft) × AC2015 (elongated hard)	Elongated hard	148 elongated hard: 85 oval semi-hard: 16 round soft	9:6:1	1.2132	0.20–0.30
EB65 (round soft) × K1140 (oval semi-hard)	Oval semi-hard	212 oval semi-hard: 68 round soft	3:1	0.0762	0.70–0.80
Non-shattering vs shattering grain					
EB65 (non-shattering) × AC766 (shattering)	Non-shattering	105 non-shattering: 79 shattering	9:7	1.362	0.20–0.30
Karan1062 (non-shattering) × AC766 (shattering)	Non-shattering	115 non-shattering: 82 shattering	9:7	2.122	0.10–0.20
Erect vs droopy spike					
Karan 3 (erect) × EB 65 (droopy)	Erect	219 erect: 81 droopy	3:1	0.640	0.70–0.80
Karan 3 (erect) × Karan 163 (droopy)	Erect	298 erect: 97 droopy	3:1	0.041	0.80–0.90
Karan 521 (erect) × EB 65 (droopy)	Erect	316 erect: 101 droopy	3:1	0.135	0.70–0.80
Karan 521 (erect) × Karan 163 (droopy)	Erect	278 erect: 88 droopy	3:1	0.178	0.50–0.70
2-rowed vs 6-rowed type					
EB 7576 (2-rowed) × Karan 3 (6-rowed)	2-rowed	198 two-rowed: 16 six-rowed	3:1	0.105	0.70–0.80
EB 7576 (2-rowed) × Karan 16 (6-rowed)	2-rowed	212 two-rowed: 67 six-rowed	3:1	0.144	0.70–0.80

allelec dominant genes (*Sh1* and *Sh2*) show complementary gene effect when present together in homozygotes (*Sh1Sh1Sh2Sh2*) or in heterozygotes (*Sh1Sh1Sh2sh2, Sh1sh1Sh2Sh2, Sh1sh1Sh2sh2*), the resulting genotypes being shattering types. However, when they are present singly in homozygotes (*Sh1Sh1* or *Sh2Sh2*) or in heterozygotes (*Sh1sh1* or *Sh2sh2*), the genotypes are non-shattering. F_3 behavior (data not shown) confirmed the good fit to a 9:7 ratio (Table 1). Chapman and Hockett (1976) report that kernel shattering resistance is complex, sensitive to environmental factors and is recessive with a significant additive epistatic component, but their study used hulled barley only.

Spike posture

Results of the spike-posture (erect vs droopy) studies are given in Table 1. The data indicate that the trait is monogenically controled (3:1) where erect (*DD*) is dominant over droopy (*dd*). The F_3 progeny behavior (data not shown) confirms the good fit of 3:1 ratio obtained in F_2 progeny.

Number of rows (2-row vs 6-row barley)

The genetic analysis of number of rows (Table 1) indicated that this trait is controled by a single gene pair (*R, r*) where the 2-rowed (*RR*) type is dominant over the 6-rowed type (*rr*). Observations made in the F_3 generation (data not shown) confirm the findings of the F_2 segregation. Imam (1959), Le Baron (1959) and Nilan (1964) report similar results in hulled barley.

It is concluded that threshability, shattering, spike-posture characters and number of rows in hull-less barley are governed by one or two genes that segregate according to simple Mendelian inheritance. Therefore, methods such as pedigree, SSD or backcross breeding may be used effectively to improve hull-less barley for the above traits.

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Evaluation of Embryogenic and Androgenic Potentials in Tissue Cultures of Moroccan Barley

تقييم إمكانات توليد الأجنة والهرمونات الذكرية في زراعة نسج من شعير مغربي

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Abstract

In-vitro **experiments were conducted to evaluate embryogenic and androgenic potentials in tissue cultures of 10 cultivars (four 2-row and six 6-row) and 10 local populations (6-row) of barley (*Hordeum vulgare* L. subsp. *vulgare*). Results indicated significant genotypic variability among Moroccan germplasm. Immature embryos from 2-row cultivars produced callus, with somatic embryos in 30.6% of cultures compared with only 2.9% in 6-row derived cultures. Similar differences were noted for callus production from cultured anthers.**

Key words: *Hordeum vulgare*; barley; *in vitro* experimentation; embryonic development; anther culture; genetic variation; callus; tissue culture; Morocco.

الملخص

أجريت تجارب مخبرية لتقييم توليد الأجنة والهرمونات الذكرية في زراعة نسج عشرة أصناف (أربعة ثنائية الصف وستة سداسية الصف) وعشر عشائر محلية (سداسية الصف) من الشعير. وأشارت النتائج إلى تباين وراثي كبير بين الأصول الوراثية المغربية. فقد أعطت الأجنة غير الناضجة من الأصناف الثنائية الصف، الكالوس (الثفن) مع أجنة جسدية في 30.6% من النسج مقارنة بـ 2.9% فقط في النسج المستخلصة من الأصناف السداسية الصف. ولوحظت فروقات مشابهة بالنسبة لإنتاج الكالوس من المآبر المزروعة.

Introduction

Barley is the world's fourth most important crop in terms of cultivated area. It is used for human and animal feed and for beer production. Morocco is an important barley producer in Africa with about 45% of the continent's area. Barley is grown mainly on poor soil and where precipitation is frequently low, since it is known for its drought tolerance – it has the best water-use efficiency among cultivated cereal species and the lowest respiration rate.

Methods for increasing the stress tolerance and production of barley include traditional breeding and, more recently, tissue culture. Shoot regeneration from immature embryo- and anther-derived callus culture has been reported in barley by many authors (Foroughi-Wehr et al. 1982; Hanzel et al. 1985; Ahloowalia 1987; Xu et al. 1989; Richard et al. 1990). It has been shown that shoot regeneration from callus depends mainly on genotypic factors, but also on environmental factors.

For success in a breeding program using tissue culture techniques, high regenerative genotypes are an advantage. Considering the genotypic variability in Moroccan barley germplasm, a high probability exists of finding responsive genotypes in available material. In the present paper, we report results of screening Moroccan germplasm using 10 local populations and 10 cultivars. Populations were screened for ability to produce callus and regenerated plants using immature embryos and anthers as a source.

Material and Methods

The plant material used for this investigation consisted of four 2-row cultivars (Asni, Tissa, Tamelalet and 895), six 6-row cultivars (905, A68, A176, 071, 077 and 628), and ten 6-row Moroccan populations of barley collected from different regions. The seeds were sown in the greenhouse in 20-cm diameter pots filled with 50% soil and 50% peat, or were sown directly in the field next to the laboratory. The sowing period extended from October to March to ensure long-term availability of explants for culture. Each cultivar or population was sown every two weeks. Thus, we were able to initiate new cultures from January to May.

For anther culture, spikes were collected when microspores were in the uninucleate stage. Spikes were subjected to cold stress for 3 to 5 days at 4°C and then to osmotic stress in 0.8 *M* sucrose solution for one hour.

Anthers were inoculated on three culture media: C17 (Wang and Chen 1986), modified MS (Foroughi-Wehr et al. 1976), and Chinese Potato 2 (Chuang et al. 1978). The three media were solidified with 0.8% agar and differed in their sucrose concentration, mineral, vitamins and organic components.

For immature embryo cultures, spikes were collected two weeks after anthesis, when embryos were 0.5 to 0.8 mm long. Spikes were subjected to cold treatment for 5 to 7 days at 4°C. Immature embryos were inoculated on MS basal medium supplemented with 2 mg 2,4-D, 30 g sucrose, and 8 g agar per liter. The pH was adjusted to 5.56 before autoclaving.

All cultures were incubated at 25°C in a growth chamber. After four weeks under 16-h photoperiods, immature embryo-induced callus was transferred to growth medium which had a reduced hormone and sugar content of 0.5 mg 2,4-D and 20 g sucrose per liter. Induction rate and embryogenic callus frequency were recorded.

After 4 to 6 weeks in darkness, microspore calli were transferred directly to regeneration media which consisted of two basal mineral compositions, C17 and R19 (Wang and Chen 1986), supplemented with 20 g sucrose and 8 g agar per liter.

Statistical analysis was carried out by the Chi-Square test or by the proportion comparison method (Bartley 1937).

Results and Discussion

Immature embryo culture

The callus induction rate and frequency of somatic embryos on callus derived from immature embryo culture varied significantly within local barley populations and cultivars. The 2-row cultivar Asni showed the highest callus formation and embryogenic ability with 83.51% and 56.43% of cultures responding, respectively. In general, 2-row cultivars had higher responses for both characters than the 6-row cultivars. The contrast method demonstrated the statistical significance of the difference between 2-row and 6-row cultivars. Nearly a third of immature embryos from 2-row cultivars produced embryogenic structures compared with 2.5 and 5.5% in the 6-row cultivars and the local populations, respectively (Table 1).

Table 1. Immature embryo response to *in-vitro* culture in different germplasm groups.

Type of germplasm	Induction (%)	Embryogenesis (%)
2-row cultivars	62.53	30.80
6-row cultivars	51.95	2.51
6-row populations	21.72	5.53
Mean	45.40	12.93

Genotypic influence on somatic embryogenesis has been reported and constitutes a major variable factor in results of tissue-culture experiments (Foroughi-Wehr et al. 1982; Hanzel et al. 1985; Godovikova et al. 1989; Xu et al. 1989). Barley somatic embryogenesis depends on three factors: callus induction, callus maintenance, and callus differentiation (Orton 1979). Callus induction showed large variations within the immature embryo populations cultured. The percentage of immature embryos giving rise to callus ranged from 0, in some local populations (Fig. 1), to 93 in the 905 cultivar (Fig. 2). This degree of variability in callus formation is equivalent to that noted by Ahloowalia (1987) and Xu et al. (1989) for their genotypically diverse germplasm.

Differences between the response of 2-row and 6-row cultivars are reported by Hanzel et al. (1985). The callus induction rate in their five best 2-row cultivars was 55% compared with only 35% in their five best 6-row ones. In our experiment, comparable induction rates were 60% and 48%, respectively.

Most calli appeared translucent and watery. However, in some genotypes, such as Asni, compact and globular structures were frequent. This callus type showed green spots and sometimes formed shoots even before transfer to regeneration medium.

The frequency of somatic embryogenesis in callus varied widely within the studied material. It was maximum in Asni (56.4%) and did not occur in three 6-row cultivars. Hanzel et al. (1985) found only 6 of 91 barley cultivars formed compact globular structures.

The embryogenic potential of callus was influenced by variety. Two-row cultivars formed more compact callus after one month of culture than 6-row material (Table

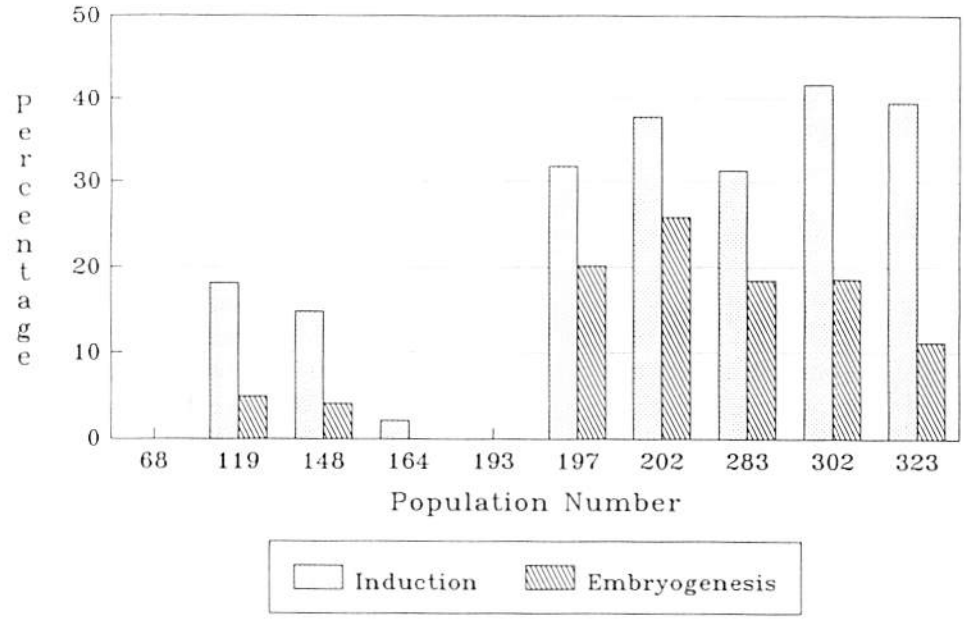

Figure 1. Immature embryo response in Moroccan populations of barley.

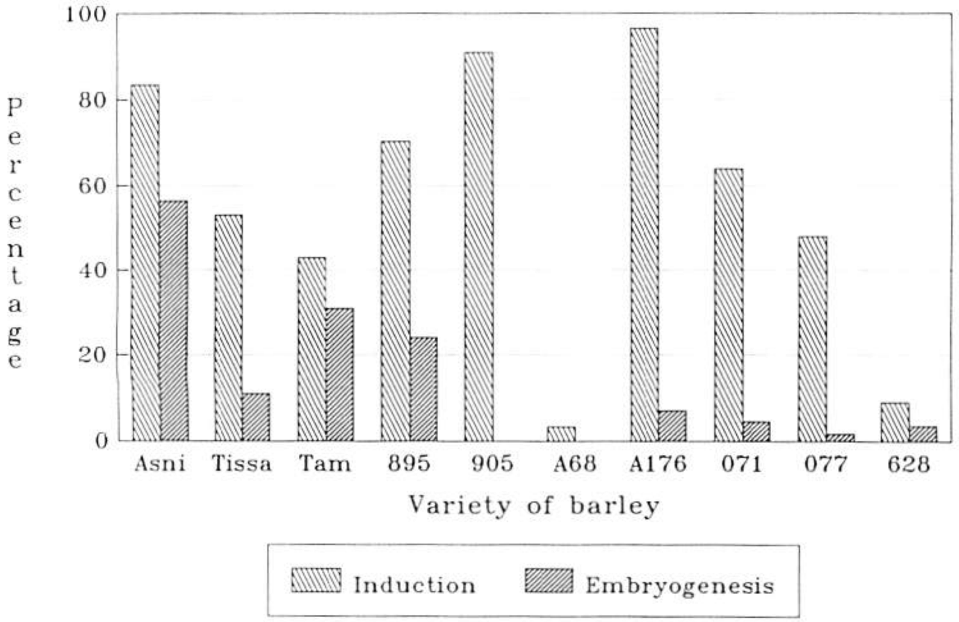

Figure 2. Immature embryo response in Moroccan cultivars of barley.

1). Callus quality also varied considerably among the genotypes studied by Godovikova et al. (1989) and Xu et al. (1989).

Cultivars which formed lots of callus were generally not those with high levels of embryogenesis. The most callogenic cultivar, 905, had no somatic embryogenesis. Bianchi et al. (1988) and Komatsuda et al. (1989) report similar results. Embryogenic ability was independent of callus quantity (r=0.20, ns).

Anther culture

Genotypic variability in the response of anthers to *in-vitro* culture was confirmed. Induction rates, which represented the number of induced microspores per 100 plated anthers, ranged from 48.1% and 38.1% for the 2-row cultivars, Sabarlis and Asni, to 3.6% for A68, a 6-row cultivar, and 1.95% for 302, a local population (Fig. 3).

In general, 2-row cultivars showed the same dominance in the response of anthers to culture as noted for immature embryos. Six-row material showed a relatively low response to anther culture. Callus induction rates from anthers were 6.55 and 7.36% for local populations and 6-row cultivars, respectively (Table 2).

Some authors designate two major components in the androgenic potential: callus induction and shoot regeneration. Foroughi-Wehr et al. (1982) distinguished two other components: callus stabilization and green-plant frequency. Each character corresponds to an androgenic differentiation step and should be controled by certain genetic factors and probably epigenic one(s) also.

Androgenic techniques deserve more research than those of somatic tissue culture because of the advantage of androgenesis in plant breeding and basic genetics. Androgenesis permits more efficient selection of recessive characters residing in homozygous plants and speed up cultivar creation programs. However, most reported works concerned cultivars of restricted use which happen to have good androgenic ability.

Table 2. Anther response to *in-vitro* culture in different genotype groups.

Type of germplasm	Induction (%)	Embryogenesis (%)
2-row cultivars	38.16	11.10
6-row cultivars	7.36	2.88
6-row populations	6.55	2.45
Mean	23.41	7.50

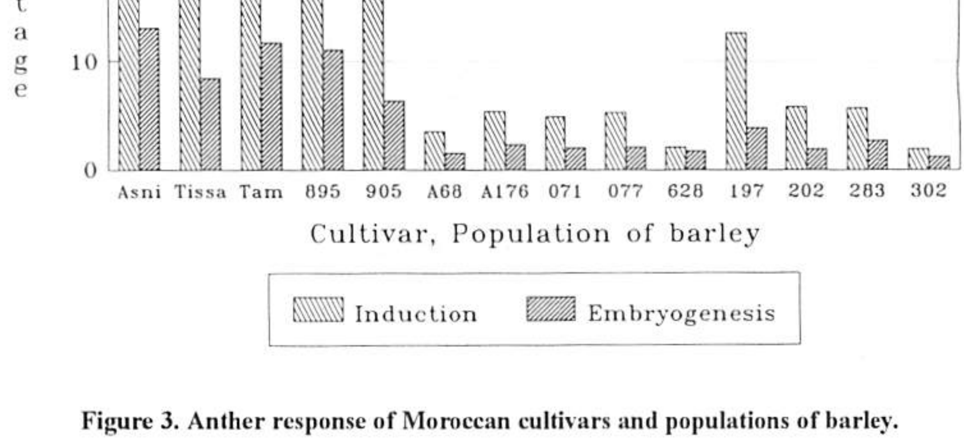

Figure 3. Anther response of Moroccan cultivars and populations of barley.

Variability in callus induction from anthers was significant in the tested material. All cultivars studied induced at least a few calli. However, induction rates varied considerably between genotypes. A number of other authors have reported large genotypic variability for this criterion. In *Hordeum vulgare*, Foroughi-Wehr and Fried (1981) achieved an induction rate of 73%. In *Triticum aestivum*, Jones and Petolino (1987) obtained a maximum of 61% induction with cv Amigo, and Han-Min et al. (1990) achieved 52% with cv Pavon.

Callus induction from anthers was significantly different among variety groups. Two-row cultivars formed more cellular proliferations than 6-row ones (Table 2). Foroughi-Wehr and Fried (1982) report similar results. Callus induction from cultured anthers is therefore related to the number of spike rows. Genetic factor(s) causing the anther response might be situated on the same linkage group as the *V* gene (Nilan 1964) which controls number of rows in barley.

Regeneration frequency from androgenic callus is another independent genetic factor which influences the ultimate yield of the technique (Lazar et al. 1984). Haploid plant formation frequency is largely dependent on the genotype. Our results permit the confirmation of both genetic control and genotypic variability. Regeneration frequency was variable and relatively low (4.51%). Foroughi-Wehr and Fried (1981) obtained from 0.3 to 4.8% regeneration. In *Triticum aestivum*, cv Chris gave a 12% regeneration rate (Han-Min et al. 1990).

Green plant frequency among regenerated plants was also affected by genetic factors. The highest rate was obtained with variety Sabarlis (52.2%), while the average rate was only 14.5%. In the experiments of Richard et al. (1990), anther culture yielded 4 green plants per 100 cultured anthers.

Genotypic influences seemed to affect both somatic and androgenic tissue culture potentials in a similar fashion. Cultivars that performed well in immature embryo culture had a good response in anther culture too (r=0.64).

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Source Reduction and Comparative Sink Enhancement Effects on Remobilization of Assimilates during Seed Filling of Old and New Wheat Varieties†

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Abstract

Four wheat (*Triticum aestivum* L. subsp. *aestivum*) cultivars were subjected to partial removal of upper leaves or awns (source) or spikelets (sink) at anthesis in an attempt to quantify the remobilization of assimilates from the vegetative parts to the grain between anthesis and maturity. The cultivars responded differently to the various removal treatments. However, there was a general trend of enhanced remobilization of assimilates from the stem and sheath to the grain following the removal of source elements; leaf removal had a greater effect than awn clipping. In contrast, the reduction in number of spikelets generally decreased the remobilization of assimilates.

Key words: *Triticum aestivum;* soft wheat; leaves; glumes; spikelets; seed filling; Pakistan.

تأثير انخفاض السفا والتعزيز النسبي للسنيبلات على إعادة انتقال السوائغ خلال امتلاء البذور في أصناف قديمة وجديدة من القمح

الملخص

عُرِّضت أربعة أصناف من القمح (*Triticum aestivum* L. subsp. *aestivum*) لإزالة جزئية للأوراق العليا أو السفا أو السنيبلات في طور الإزهار وذلك في محاولة لتحديد مدى انتقال السوائغ من الأجزاء الخضرية إلى الحب بين الإزهار والنضج. وقد استجابت الأصناف لمعاملات الإزالة المتعددة بصورة مختلفة، غير أن هناك اتجاهاً عاماً لتعزيز إعادة انتقال السوائغ من الساق والغمد إلى الحب بعد إزالة عناصر السفا، وكان لإزالة الأوراق تأثير أكبر من قطع السفا. وعلى النقيض من ذلك، فإن التناقص في عدد السنيبلات قد خفض عموماً إعادة انتقال السوائغ.

Introduction

Wheat is a determinate plant that produces a terminal spike at the end of the vegetative period. Before the linear phase of dry-matter accumulation in the kernels, net assimilation exceeds the requirements of growing grains and, since there is no other sink owing to the determinate nature of the plant, the soluble carbohydrates accumulate in the stem and leaf sheath to levels up to 2 tonnes per hectare (Hays and Walker 1989). Winzeler et al. (1989) report that large amounts of assimilates accumulate as non-structural carbohydrates in the stems of tall genotypes at maturity under high CO_2 concentration. Results obtained by Davidson and Chevalier (1992) indicate that culms are important temporary storage sites for reserve carbohydrates in irrigated as well as non-irrigated plants; they recorded an increase in water-soluble carbohydrates up to 280 mg per gram of dry weight of stem 10–14 days after anthesis, which then declined to 50 mg till maturity. The photosynthates stored as reserves in the stem and other organs can be remobilized when photosynthesis is insufficient to meet the demands for, e.g., grain-filling.

† Part of MSc research conducted by the first author.

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Remobilization varies with variety. Mkamanga (1985) reports that remobilization of leaf assimilates formed at anthesis ranged from 15 to 47% in different varieties and concludes that efficient remobilization of early-formed assimilates may be a useful selection criterion. Yield could be increased by efficient mobilization of reserves. Knowledge of how to increase storage and remobilization of assimilates is important for increasing productivity of wheat. As little information is available on remobilization of dry matter from stem of wheat tillers, an experiment was designed to study the effect of source–sink manipulation on tiller productivity.

Material and Methods

The experiment was conducted at Malkandher farm of the North West Frontier Province Agricultural University, Peshawar, Pakistan in 1991/92. The experimental site is located at 34.01°N, 72.3°E, at 450 m altitude. The soil of the experimental site was low in organic matter and nitrogen, and alkaline. Four wheat varieties – C591, C273, Pak-81 and Pirsabak-85 – were used. The first two varieties are old and were developed from crosses between landraces. The latter two are new, dwarf, high-yielding varieties developed from material received from the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) in Mexico.

The four varieties were planted on 24 November 1991, in a well-prepared field using a randomized complete block design with four replications. Plot size was 1.5 × 3 m. At anthesis, 14 source and sink manipulation treatments along with a control were applied. The source-reduction treatments comprised removal of one-quarter, half, three-quarters and all awns; half flag leaf, flag leaf, flag leaf + half penultimate leaf, top two leaves, and all leaves; and all leaves + awns. The sink-reduction treatments comprised removal of two, four, six and eight spikelets. The treatments were arranged in a split-plot arrangement for the 4 × 15 two-factorial experiment, with varieties in main plots and source–sink manipulation treatments in sub-plots.

At anthesis, five tillers per main plot were harvested, dried in an oven at 70°C for 48 hours, and stem with sheath weight was recorded. At maturity, the tillers to which treatment had been applied were harvested and oven-dry mass of stem with sheath was recorded. The difference between stem with sheath mass at maturity and at anthesis was used as an estimate of the dry matter remobilized from stem and leaf sheath to grains.

The following linear model was used for the analysis of data from sub-plot treatments:

$$Y_{ijk} - \mu + \rho_i + \alpha_j + \varepsilon_{ij} + \beta_k + (\alpha\beta)_{jk} + \delta_{ijk}$$

where:

Y_{ijk} = any observed value of the response variable

μ = general population mean or constant

ρ_i = blocks effects

α_j = main-plot treatments effects i.e. varieties effects

ε_{ij} = random effects or error associated with main-plots

β_k = sub-plot treatments effects i.e. source–sink effects

$(\alpha\beta)_{jk}$ = interaction effects

δ_{ijk} = random effects or error associated with sub-plots.

Least significant difference test (LSD) was used to test the differences among the four varieties and differences between control and source–sink manipulation treatments. Trend analysis was used to quantify the effect of the removal of awns, leaves and spikelets on remobilization of dry matter from stem and leaf sheaths to grains.

Results and Discussion

Data on remobilization of assimilates in wheat varieties as affected by source–sink manipulation are given in Table 1. Source–sink manipulation treatments significantly affected remobilization of assimilates from stem and leaf sheath to grains (Table 2). Source reduction and comparative sink enhancement increased remobilization from stem to grains. Removal of awns and leaves increased remobilization of dry matter to grains. Generally, leaf removal had more effect on remobilization than awn removal, as removal of one milligram of leaf tissue increased remobilization from stem by 4.91 mg/tiller (Fig. 1), compared with an increase of 1.485 mg dry matter per tiller for each milligram of awn tissue removed (Fig. 2). Remobilization from stem to grains

Table 1. Remobilization of assimilates (mg/tiller) from stem and leaf sheath to grains of four wheat varieties as affected by source–sink reduction treatments, NWFP Agricultural University, Peshawar, 1991/92.

Treatment	C591	C273	Pak-81	Pirsabak	Mean
Control	173.79	-116.49	29.47	-150.32	-15.89
¼ awns cut	188.70	-99.52	262.20	-148.58	50.70
½ awns cut	-122.81	-91.00	132.93	7.55	-18.33
¾ awns cut	74.24	-53.49	210.35	313.15	136.06
All awns cut	371.81	-62.20	226.17	106.12	160.47
½ flag leaf cut	271.47	35.45	347.53	-90.57	140.97
Flag leaf cut	287.77	130.34	242.44	42.11	175.67*
Flag and ½ next leaf cut	64.24	136.54	345.21	240.21	196.55*
Flag and next leaf cut	456.86	282.86	215.35	156.35	277.85*
2 spikelets removed	139.10	-31.23	261.04	74.51	110.86
4 spikelets removed	214.90	104.27	24.82	-35.24	77.19
6 spikelets removed	166.07	2.93	40.63	139.40	87.26
8 spikelets removed	-132.38	7.96	228.03	32.34	33.99
All leaves removed	361.41	230.48	244.30	283.60	279.95*
All leaves and awns removed	386.18	196.38	225.70	253.76	265.50*
Mean	193.42	44.89	202.41	81.63	130.59

* Significantly different from control.

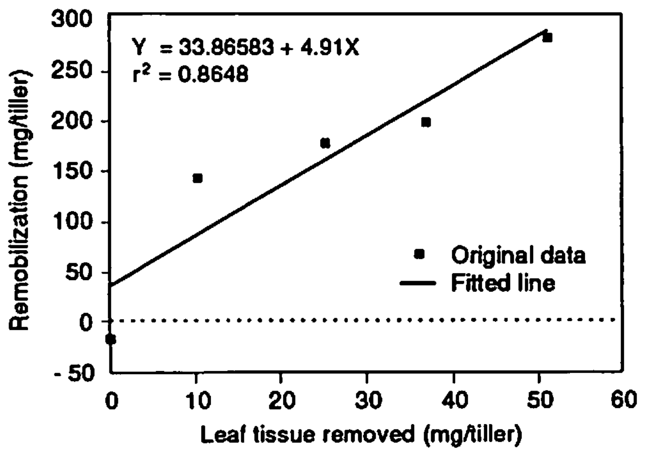

Fig. 1. Effect of leaf-tissue removal on remobilization of dry matter from stem and leaf sheath to grains of wheat.

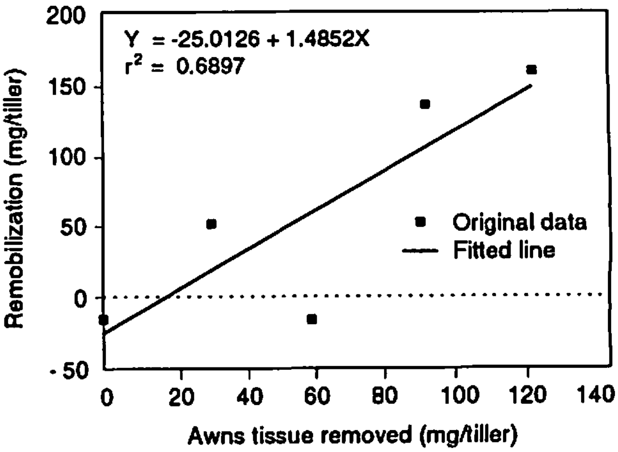

Fig. 2. Effect of awn-tissue removal on remobilization of dry matter from stem and leaf sheath to grains of wheat.

was less in tillers with sink reduction (Fig. 3). Remobilization decreased from about 111 mg/tiller with two spikelets removed to about 34 mg/tiller with eight spikelets removed. Trend analysis showed that remobilization decreased at the rate of 11.03 mg/tiller for each reduction of the reproductive-sink size by one spikelet. In control plots there was no remobilization from stem to grains, rather there was an accumulation of about 16 mg dry matter in the stem of tillers. Thus, under conditions encountered by the wheat crop in this experiment, source was not limiting to tiller yield.

Table 2. Analysis of variance table for remobilization of assimilates (mg/tiller) of four wheat varieties as affected by varieties and source and sink manipulation treatments.

Source of variation	d.f.	Sum of squares	Mean square	F
Replications	3	6749	2250	0.00
Varieties (V)	3	1130944	376981	0.54 ns
Error I	9	6268319	696480	
Treatments (T)	14	2145200	153229	3.75*
V × T	42	2320988	55262	1.35***
Error II	168	6873219	40912	
	SE	LSD (0.05)	LSD (0.01)	
V	152.368			
Source–sink treatments	71.512	161.76	232.41	
V × T	143.024			

ns = not significant; * = significant at $P \leq 0.01$; *** = significant at $P \leq 0.1$.

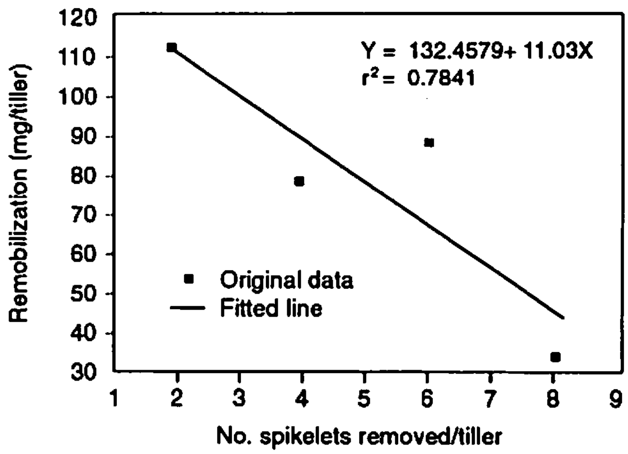

Fig. 3. Effect of number of spikelets on remobilization of dry matter from stem and leaf sheath to grains of wheat.

Averaged over the source–sink manipulation treatments, there were no significant differences among the four varieties for remobilization from stems and leaf sheaths, despite the fact that more dry matter was mobilized from stems and leaf sheaths in Pak-81 and C591 than in Pirsabak-85 and C273. This could be a result of fewer degrees of freedom for type-I error and greater random variation.

Interaction between the four varieties and the source–sink manipulation treatments was significant ($P \leq 0.1$), indicating that the four varieties responded differently to the source and sink reduction treatments. In the control tillers of Pirsabak-85 and C273 there was negative remobilization, i.e. there was dry matter storage in the stems and leaf sheaths, indicating assimilate production in excess of the requirements for grain-filling. In the control tillers of Pak-81 there was little remobilization, and in those of C591 there was more remobilization. Awn removal had different effects on remobilization in the four varieties: in C273 there was negative remobilization in tillers with clipped awns, but awn removal generally increased mobilization in the other three varieties.

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Wheat Breeding for Resistance to Septoria Nodorum Blotch in Croatia

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Abstract

Laboratory studies on the fungus *Leptosphaeria nodorum* Müller at the Institute for Plant Protection in Agriculture and Forestry, Zagreb, Croatia, have been aimed at selecting the best isolates for inoculum production to be used in artificial infection, based on individual morphology, physiology and virulence. Inoculum was produced on sterilized wheat (*Triticum aestivum* L. subsp. *aestivum*) kernels. Artificial infection was performed on seedlings in the greenhouse, and on adult plants in the field. The purpose of the investigation was to test domestic and foreign wheat for resistance to local isolates of this fungus, placing particular emphasis on the reaction of known sources of resistance.

Key words: *Triticum aestivum*; blotches; *Leptosphaeria nodorum*; disease resistance; plant breeding; Croatia.

تربية القمح لمقاومة التبقع السيبتوري في كرواتيا

الملخص

هدفت الدراسات المخبرية على الفطر *Leptosphaeria nodorum* Müller التي جرت في معهد وقاية النبات في الزراعة والحراج في زغرب بكرواتيا، إلى انتخاب أفضل العزلات لإنتاج لقاح بغية استخدامه في العدوى الصناعية وذلك بالاستناد إلى مظهره وفيزيولوجيته وفوعته. وقد تم إنتاج لقاح على حبات معقمة من القمح (*Triticum aestivum* L. subsp. *aestivum*). وأجريت العدوى الصناعية على البادرات في الدفينة وعلى نباتات كاملة في الحقل. وكان الهدف من هذه الدراسة اختبار القمح المحلي والأجنبي من حيث المقاومة للعزلات المحلية من هذا الفطر مع التركيز بشكل خاص على رد فعل مصادر المقاومة المعروفة.

Introduction

Intensive cultural practices favor the spread of septoria nodorum blotch disease. Breeding work has also accelerated the development and spread of this severe spike disease. Wheat genotypes suited to intensive management tend to be short. These genotypes were able to withstand increased nitrogen rates and denser stands without lodging. By shortening the internodes, the gap between different leaf positions was shortened, permitting faster spread of the disease from the tiller base to the spike. This problem is discussed by Bronnimann (1975).

Material, Methods and Objectives

In Croatia, the Department of Cereal Crops at the Institute for Breeding and Production of Field Crops was the first to allocate resources to breeding programs for resistance to the causal organism of septoria nodorum blotch, i.e. the fungus *Leptosphaeria nodorum* Müller (= *Septoria nodorum* (Berk.) Berk.). Work at Botinec was initiated in 1974 and intensified in 1980 (Korić 1983). Intensification was possible because the method of growing the isolate and production of *L. nodorum* in pure culture was successfully mastered. Growing this fungus in pure culture in the laboratory enabled the selection of the best isolate for the production of inoculum for artificial infection, based on morphological and physiological traits of individual isolates, as well as on tested virulence. The inoculum was produced on sterile wheat kernels substrate (Fried 1989). In this way, it was possible to test an assortment of wheat genotypes as seedlings in the greenhouse and as adult plants in the field. We tested wheat response to domestic isolates, paying special attention to the reaction of well-known sources of resistance from all over the world; we were also checking for any correlation between resistance in seedlings and that in adult plants. The entire breeding material obtained from crossing selected foreign and domestic sources of resistance was tested. Crossing allows commutation of more resistance genes in plants, thus raising the levels of resistance. New sources of resistance obtained in pre-selection will serve for further breeding.

Investigation in seedlings serves two purposes. The first objective is to test the possibility of using seedlings to screen for sources of resistance and tolerance, and as a quick and effective method for testing successfulness of resistance incorporation through breeding. Second, seedlings are used to determine virulence of individual isolates for use in artificial infection.

The estimation of severity in seedlings and adults followed internationally recognized methods (Bronnimann 1968, 1975; Saari and Prescott 1975). When estimating disease severity, it must be noted that not all leaf positions on a plant were equally affected nor were their effects on yield identical. There were genotypes in which the apical leaf was completely healthy, while other leaves were more or less infected. There is also a difference in susceptibility between leaves and spikes: one genotype can be susceptible to *L. nodorum* on its leaves without showing any symptoms on its spikes.

Selection of sources of resistance in the adult stage was based on reaction of each wheat genotype to *L. nodorum* on leaves and spikes. All genotypes that exhibited severe infection on ears or apical leaves were discarded from further testing. Genotypes showing very little or no infection (up to 10%) on lower leaves were taken as possible sources of resistance. The effect of septoria nodorum blotch on yield, yield components and sanitary seed condition was investigated previously (Korić 1989b).

The rate of kernel infection with *L. nodorum* was determined by the deep-freezing blotter method (Mathur 1977). In seedlings and adults, under conditions of artificial infection with a population of selected and tested *L. nodorum* isolates, we studied the correlation between certain genotypes for their resistance to infection by the fungus (Korić 1989a). In addition, we used the Spearman's rank correlation to test the relationship between seedling resistance and adult resistance, in order to use early testing as a screening tool in breeding for resistance to septoria nodorum blotch.

Results and Discussion

Severe infestation by septoria nodorum blotch can reduce wheat yield by up to 50% in Croatia (personal observation). These are just the direct losses in one season. One must also consider indirect damage, which becomes obvious in the following season. The fungus can cause infection deep inside the kernel, giving over 70% infection under severe spike infection (Korić 1987). If such infected seeds are planted, damage becomes evident as early as germination and emergence, when the fungus destroys the germ or kills the emerged seedlings. Plant density is thus reduced, which finally results in reduced yield. Since the causal organism of this disease is transmitted through kernels, special care must be taken in seed production. Also, severe attacks can affect seed quality by reducing kernel size. Seeds produced from diseased crops are smaller, so there are more discarded seeds and smaller grades in processing. The sanitary condition of such seeds is not satisfactory because of the high rate of infected kernels (Table 1).

Testing has shown that foreign sources of resistance are mostly satisfactory and can therefore be used in breeding for resistance to *L. nodorum* in Croatia (Table 2). Wheat genotypes from Russia, Brazil and the USA exhibited high levels of resistance. Some domestic genotypes, especially ZG 3021/84, were equally resistant.

Virulence of isolates was tested on an assortment of wheat genotypes with different morphological, biological and physiological traits, following Scharen et al. (1985). Virulence of individual isolates was estimated based on the number of avirulent and virulent genes of

Table 1. Effect of septoria nodorum blotch on quality and sanitary seed condition.†

Infection source	<2.2		2.2		2.5		>2.8	
	mm	%	mm	%	mm	%	mm	%
				Share of seed grades				
Natural	6.6	100	13.0	100	32.6	100	47.8	100
Artificial	7.7	117	21.2	163	45.1	138	26.1	54.6
				Kernel infection in seed grades				
Natural			8	100	5	100	6	100
Artificial			65	812	57	1140	41	683

† Analysis made after passed aspiration.

Table 2. Reaction of wheat genotypes to septoria nodorum blotch.

Genotype	Origin	Mean rating of *L. nodorum* attack (%)		
		Leaf	Spike	Seedling
Arthur 71	USA	67	0	0
Delta Queen	USA	55	0	0.4
MT 76/60	USA	77	0	5.6
Complex	USA	75	0	0.2
Iassul 20	USA	67	0	0
Pat. 10	USA	57	0	0
P.F. 70131	USA	58	0	0
Osage	USA	68	0	0
Oassis	USA	68	0	2.2
IAS 54	USA	58	0	3.7
NB 69633	USA	63	0	3.7
Belaja Cerkov	USSR	58	0	0.8
Mironovskaja 808	USSR	58	0	0
Dimitrovska 52	Bulgaria	68	0	8.9
Pel. 73081	Brazil	58	0	1.5
58/12	Croatia	68	0	2.5
59/11	Croatia	68	0	0
133/2	Croatia	58	0	1.0
195/9	Croatia	57	0	0
ZG 8025/82	Croatia	58	0	3.2
ZG 8084/82	Croatia	62	0	2.0
ZG 11039/82	Croatia	58	0	2.2
ZG 3021/84	Croatia	47	0	0
Zlatna dolina (check)	Croatia	88	8	27.5
Fortuna (check)	USA	68	5	5.3
Haden (check)	USA	78	3	8.5

each isolate in relation to the test assortment. In this way aggressiveness of each isolate was obtained (Table 3).

The sources of resistance and breeding material were also tested for field resistance at the adult stage under artificial infection. Timing of the artificial infection is critical for obtaining reliable results. Application of artificial infection after sunset or during cloudy weather gave excellent results and allowed us to avoid using the plastic cover recommended by many workers. By covering plots with plastic covers certain undesirable effects can be produced by the high temperatures during sunny days (personal observations).

Table 3. Virulence of *Leptosphaeria nodorum* isolates.

Virulent isolates (V)	27/86, 30/87, 13/90, 25/91
Moderately virulent isolates (MV)	72/86, 40/87, 65/87, 77/87, 79/87, 80/87, 17/88, 7/89, 16/89, 20/89, 35/89, 2/90, 10/90, 17/91
Avirulent isolates (A)	74/86, 7/87, 15/88, 26/88, 11/89, 23/89, 27/89, 1/90, 3/90, 3/91, 6/91, 9/91
Variety	**Virulent isolates**
Yamhill	2/90, 13/90 (2)
Fortuna	7/87, 65/87 (2)
ZG 3021/84	·17/88, 7/89 (2)
KVZ-UP-301	27/86, 72/86 17/91 (3)
Iassul 20	30/87, 79/87, 1/90, 2/90, 10/90 (5)
Kavkaz	27/86, 7/87, 30/87, 17/88, 10/90 (5)
Klein Titan	72/86, 30/87, 7/89, 16/89, 20/89 (5)

The correlation between infection in seedlings and adult plants ranged from weak to strong. We therefore believe that testing of the seedlings can serve as an auxiliary method, but not as the only means of screening for resistance. Resistance must also be tested in adults. This applies especially to wheat genotypes that are moderately resistant or moderately susceptible. Artificial infection with selected *L. nodorum* isolates at the adult stage in the field presents the main test for checking the incorporation of resistance into a genotype. In doing so, care must be taken that the investigations are made with the proper isolates.

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Biomass Production and Grain Yield of some Genotypes of Bread and Durum Wheat Under Coastal Mediterranean Conditions

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Abstract

A study was conducted to provide basic information on the dry-matter production, grain yield and yield structure in bread (*Triticum aestivum* L. subsp. *aestivum*) and durum (*T. turgidum* L. subsp. *durum* (Desf.) Husn.) wheat genotypes under Mediterranean climate conditions, and to obtain data related to the yield gap in the region and possible differences between bread and durum wheat. In a three-year field study, two genotypes of each of bread and durum wheat were grown under different nitrogen fertilizer and sowing rates to increase variation in yield and yield structure. In 1989 and 1990, the average above-ground biomass production was 30% higher than in 1991. Within each year the above-ground biomass yield of the genotypes was similar. The average grain yield of the four genotypes was 589, 619 and 442 g/m² in 1989, 1990 and 1991, respectively. The lower yields of the bread wheat variety Cumhuriyet were associated with lower harvest index. Grain weight and harvest index were the most pronounced differences between bread and durum types. Using

إنتاج الكتلة الحيوية والغلة الحبية لبعض الطرز الوراثية من القمحين الطري والقاسي تحت ظروف الساحلية المتوسطية

الملخص

نفذت دراسة بهدف توفير المعلومات الأساسية عن إنتاج المادة الجافة، الغلة الحبية وتركيب الغلة في طرز وراثية من القمح الطري (*Triticum aestivum* L. subsp. *aestivum*) والقمح القاسي (*T. turgidum* L. subsp. *durum* (Desf.) Husn.) تحت ظروف مناخية متوسطية، والحصول على معلومات تتعلق بفجوة الغلة في المنطقة والفروقات الممكنة بين القمحين الطري والقاسي. وفي دراسة حقلية دامت ثلاث سنوات، زرع طرازان وراثيان من كل من القمحين الطري والقاسي تحت معاملات مختلفة من التسميد الآزوتي ومعدلات الزراعة وذلك لزيادة التباين في الغلة وتركيب الغلة. وفي عامي 1989 و1990، كان متوسط إنتاج الكتلة الحيوية فوق الأرض أكثر بنسبة 30% منه في 1991. وكانت غلة الطرز الوراثية من الكتلة الحيوية فوق الأرض ضمن كل سنة متشابهة، كما كان متوسط الغلة الحبية للأصناف الأربعة 589، 619 و442 غ/م2 في 1989، 1990 و1991 على التوالي. واقترنت الغلال الأدنى لصنف القمح الطري Cumhuriyet بدليل حصاد أدنى. وكانت أبرز الفروقات بين نوعي القمح الطري والقاسي، وزن الحبة ودليل الحصاد. وقد أسفر استخدام معدلات عالية من الآزوت (120 إلى 200 كغ/هـ) والزراعة الكثيفة (450 إلى 850 بذرة/م2) عن تباين محدود في الغلة وعن عدم وجود فروقات

high rates of nitrogen (120 to 200 kg/ha) and dense sowing (450 to 850 seeds/m²) resulted in no significant yield variation and there were no major response differences between bread and durum genotypes. Variation in grain yield was closely associated with biomass production and less with harvest index. Moreover, grain yields were consistently more correlated with grains/unit area than with grain weight.

Key words: *Triticum aestivum*; *Triticum durum*; soft wheat; hard wheat; biomass; genotypes; grain; yields; mediterranean climate; Turkey.

رئيسية في الاستجابة بين الطرز الوراثية من القمحين الطري والقاسي. واقترن التباين في الغلة الحبية بشكل وثيق بإنتاج الكتلة الحيوية وبشكل أقل بدليل الحصاد. وعلاوة على ذلك، رُبطت الغلة الحبية بشكل ثابت وعلى نحو أكثر فأكثر بالحب/وحدة المساحة أكثر من ارتباطها بوزن الحبة.

Introduction

Substantial grain-yield increases have been achieved in wheat on a global basis. However, increases in grain yield in most developing agricultural countries, including Turkey, have not kept up with the world average (Briggle and Curtis 1987; Genç 1987).

Although there is much research on the morphological and physiological characters associated with high grain yield in developed countries, information is lacking in many developing areas. Moreover, research on the differences between bread and durum wheat is limited even in developed areas (Cubadda 1983; Ketata 1984).

The present study was conducted under a Mediterranean coastal-type climate where wheat is sown in autumn (fall) and harvested in early summer; thus, it is relevant to much of the Mediterranean basin (Frere et al. 1987).

To improve our understanding of yield formation and the yield gap, emphasis was placed on the biomass production, distribution and grain yield structure. Two bread wheat and two durum wheat genotypes were grown with different nitrogen and seeding rates to increase variation in relevant parameters.

Material and Methods

Three field experiments were conducted at the research area of the Agricultural Faculty, University of Çukurova, Adana, Turkey, in the Çukurova Plain (36°59'N, 38°18'E) about 35 m above sea level. The soils were sandy loam, pH 6.3–7.7; cotton was always the previous crop. Mean monthly temperature and rainfall during the growing seasons are shown in Table 1.

Two spring bread wheat genotypes, Cumhuriyet-75 and ÇÜZFT-10004, and two durum wheat genotypes, Balcalı-85 and ÇÜZFT-00006, were grown under different N fertilizer and seeding rates. In 1989 and 1990, the treatments were arranged in a split-split-plot design, with nitrogen as main plots, sowing rates as sub-plots and genotypes as sub-sub-plots, in randomized complete

Table 1. Temperature and rainfall during the growing seasons 1988/89, 1989/90 and 1990/91, Adana, Turkey.

Month	Mean temperature (°C)			Rainfall (mm)		
	1988/89	1989/90	1990/91	1988/89	1989/90	1990/91
Nov	12.6	15.8	17.7	115	92	16
Dec	11.4	11.0	12.6	91	131	65
Jan	8.3	8.0	10.2	66	18	36
Feb	11.1	10.6	10.0	†	134	94
Mar	15.0	14.2	15.0	57	59	21
Apr	20.0	17.9	18.2	‡	30	77
May	23.4	21.6	20.8	0	40	22

†, ‡ Supplemented with sprinkler irrigation of about 120 mm and 60 mm, respectively.

block arrangement with three (1989) and four (1990) replications. In 1991, four genotypes and two nitrogen rates in factorial treatment combinations were arranged in randomized complete block design with four replications. Each sub-sub-plot consisted of eight rows, 14.5 cm apart and 5 m long and was seeded with a pilot drill on 10 December 1988, 5 December 1989 and 27 November 1990. The nitrogen fertilizer rates were 120, 160 and 200 kg N/ha. Seeding rates were 450, 650 and 850 seeds/m². The 120 kg N/ha and 450 seeds/m² represented the commercially recommended rates. All plots received 50 kg (or 100 kg in 1991) of P_2O_5/ha at seeding. Nitrogen was applied in the form of ammonium nitrate in four (equal or 20%, 40%, 30%, 10% in 1991) splits at Zadoks growth stages 1.0, 2.1, 3.0 and 5.0. At harvest, the central 50-cm section of four inner rows were cut at ground level. Dry weight was determined on the whole sample after oven-drying at 70°C for 48 h.

The results from each year were analyzed separately by analysis of variance using EGE statistical analysis system (EGE University). The correlation coefficients among various characters were determined separately for each year.

Results and Discussion

The average above-ground biomass yield at maturity over all treatments and genotypes was similar in 1989 and 1990, although climatic conditions, especially temperature during the grain-growth period, were rather different (Tables 1 and 2). This indicates a ceiling to dry-matter production in these crop years. The above-ground biomass yield levels in this study were as high as under optimal conditions in Mexico (Waddington et al. 1986), England (Austin et al. 1980), Italy (Borghi et al. 1992) and the USA (Gent and Kiyomoto 1989).

Table 2. Biomass yield, grain yield and harvest index of two bread (B) and two durum (D) wheat genotypes grown under different N-fertilizer and sowing rates during the 1988/89, 1989/90 and 1990/91 growing seasons, Adana, Turkey.

Treatment	Biomass yield (g DM/m²)			Grain yield (g DM/m²)			Harvest index (%)		
	1989	1990	1991	1989	1990	1991	1989	1990	1991
Genotype (G)									
Cumhuriyet (B)	1547	1667	1159	521	548	428	33.8	32.8	37.0
Balcalı (D)	1657	1681	1123	621	661	446	38.3	39.2	39.4
ÇÜZFT 10004 (B)	1659	1771	1154	591	615	441	35.8	34.6	38.1
ÇÜZFT 00006 (D)	1702	1694	1202	624	652	454	37.2	38.5	37.6
$LSD_{0.05}$	n.s.	n.s.	n.s.	43.9	50.5	n.s.	2.90	1.68	n.s.
Sowing rate (S, seeds/m²)									
450	1662	1790	1159	571	653	442	34.8	36.8	38.1
650	1639	1696	–	618	626	–	38.0	36.8	–
850	1623	1623	–	580	578	–	36.0	35.5	–
$LSD_{0.05}$	n.s.	n.s.		n.s.	n.s.		1.80	n.s.	
N-fertilizer rate (N, kg/ha)									
120	1461	1686	1156	549	632	446	37.8	37.2	38.4
160	1706	1719	–	591	608	–	34.7	35.5	–
200	1756	1702	1163	628	617	439	36.3	36.6	37.5
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Signif. interaction	N × S × G	n.s.	n.s.	N × S × G	n.s.	n.s.	N × S	n.s.	n.s.

n.s.: not significant at $P = 0.05$.

The biomass yield at maturity did not vary significantly among genotypes or treatments (Table 2). However, there was a significant genotype × seeding rate × N rate interaction in 1989, with no consistent trends for bread and durum wheat genotypes.

Grain yields in the first two crop years were also similar, and 37% higher than in 1991 (Table 2). The lower yield in 1991 was related to fewer grains/m² and fewer ears/m² (Table 3). Grain weight showed no difference across years. Similar trends are reported from previous studies in Adana (Koç et al. 1989). Spiertz (1978) concludes that environmental factors influence the number of grains more than their weight.

Bread wheat variety Cumhuriyet gave the lowest grain yields, but differences were significant only in the first two years. There was a significant genotype × N rate × seeding rate interaction in 1989, with no clear response differences between bread and durum wheats. The responses of genotypes for grain yield were not related to their response for above-ground biomass yield (data not shown). Grain yield was not significantly affected by N or seeding rate in 1990, or by N in 1991.

The average harvest index values of genotypes ranged between 34.7 and 37.7% in 1989; 32.8 and 39.2% in 1990; and 37.0 and 39.4% in 1991 (Table 2). These values are considerably lower than those obtained under optimal conditions and the theoretical maximum (Austin et al. 1980; Borghi et al. 1992; Waddington et al. 1986). Yield differences among genotypes were related to harvest index. The lowest-yielding cultivar, Cumhuriyet, also had the smallest harvest index values. These results show that there are prospects for increasing yield beyond the recorded values by exploiting genetic variation in harvest index. Previous studies show that, until recently, yield improvements were mainly due to improvement in harvest index (Austin et al. 1980; Siddique et al. 1989).

Table 3. Yield components of two bread (B) and two durum (D) wheat genotypes grown under different N-fertilizer and sowing rates during the 1988/89, 1989/90 and 1990/91 growing seasons, Adana, Turkey.

Treatment	No. ears/m²			No. grains/m²			Grain wt (mg)		
	1989	1990	1991	1989	1990	1991	1989	1990	1991
Genotype									
Cumhuriyet (B)	702	676	427	15.29	15.78	11.36	34.6	38.6	38.5
Balcalı (D)	815	614	346	15.31	15.48	10.63	41.2	42.9	41.0
ÇÜZFT 10004 (B)	582	756	359	16.23	16.64	11.42	36.7	39.0	38.0
ÇÜZFT 00006 (D)	736	684	390	15.76	15.50	10.97	40.3	42.2	43.1
$LSD_{0.05}$	72.4	47.4	50.9	n.s.	n.s.	n.s.	2.88	1.46	n.s.
Sowing rate (S, seeds/m²)									
450	571	669	380	14.51	16.13	11.1	40.1	41.9	40.1
650	719	692	–	16.61	15.97	–	34.5	40.6	–
850	839	686	–	15.82	15.45	–	37.0	39.6	–
$LSD_{0.05}$	61.4	n.s.		1.34	n.s.		2.59	1.31	
N-fertilizer rate (N, kg/ha)									
120	751	571	383	15.36	15.77	10.98	36.4	41.1	41.6
160	686	696	–	15.08	16.00	–	39.8	41.3	–
200	689	780	377	16.51	15.78	11.21	38.5	39.7	38.7
$LSD_{0.05}$	n.s.	41.3	n.s.	n.s.	n.s.	n.s.	n.s.	1.04	n.s.
Signif. interaction	n.s.	n.s.	n.s.	N × S	n.s.	n.s.	n.s.	n.s.	n.s.

The most pronounced differences between bread and durum wheat genotypes were in harvest index and grain weight (Tables 2 and 3). Where yield differences were evident, grain weight for durum genotypes was greater than that for bread genotypes, and differences in harvest index were associated more with the grain weight than with the number of grains/m². Although grain weight was slightly less in denser crops, it was not sufficient to nullify the effect of more ears and grains/m².

Genotype differences were not consistent across years for number of ears. Grains per unit area showed no differences among genotypes. The number of grains under Adana conditions was considerably lower than that recorded under high-yielding conditions (Spiertz 1978).

Considering all management levels over the three years, there were no major response differences between the genotypes (Tables 2 and 3). There was no evidence that the durum genotypes required more nitrogen or responded better to nitrogen. Using high rates of nitrogen (120–200 kg/ha) resulted in no significant yield response, despite the range of different climatic conditions observed in these experiments. Decreased nitrogen efficiency has often been observed with increasing rates of nitrogen application (Caldwell and Starratt 1987; Campbell and Davidson 1979; Fredrick and Marshall 1985; Pearman et al. 1977). Campbell and Davidson (1979) suggest that inefficient use of nitrogen is associated with increased stress caused by excessive vegetative growth. It could be questioned whether such stress occurred in 1989 and 1990, where the biomass yields were high, but nitrogen affected the biomass yield only slightly in 1989, no nitrogen effect was observed in 1990, and no substantial lodging occurred. Part of the decrease in nitrogen efficiency can be attributed to the decrease in received light intensity or increase in evapotranspiration that could result from excessive vegetation (Pearman et al. 1977). Nitrogen resulted in a significant increase in leaf area index in 1989. A similar trend was observed in other years (data not shown). The nitrogen inefficiency in 1991 seems to be related more to limited water supply. Soil nitrogen level prior to sowing was low in that season (0.09%). Published data provide evidence for the dependence of nitrogen use on soil water avaibility (Black and Aase 1982; Eck 1988). These data point to the need for more information on nitrogen fertilizer recommendations for wheat grown under limited and fluctuating rainfall.

Correlation of grain yield with other traits was consistent over the three years (Table 4). Variation in grain yield was closely associated with above-ground dry weight and moderately so with harvest index. Thus, grain yield varied with biomass production and distribution. Austin (1987) suggests that genetic improvements in biomass yield are likely to be much more difficult to achieve than improvement in harvest index. Moreover, environmental factors influence the biomass production more than its distribution (Austin 1987), as also shown in this study. The fact that crops produce sufficient biomass to maximize their yield, suggests that breeding should aim to increase harvest index to increase yield. Increased harvest index is considered a desirable trait for greater yield and stability in environments with reduced and fluctuating rainfall (Acevedo 1991).

Table 4. Correlation (r^2) of grain yield with biomass yield, harvest index and yield components during the crop seasons 1988/89, 1989/90 and 1990/91, Adana, Turkey.

	1988/89	1989/90	1990/91
Biomass yield	0.632**	0.757**	0.873**
Harvest index	0.501**	0.616**	0.507**
No. ears/m²	0.182	0.148*	-0.539*
No. grains/m²	0.709**	0.745**	0.731**
Grain wt	0.340**	0.252**	-0.287
n	106	142	22

*,** Significant at $P = 0.05$ and 0.01, respectively.

Grain yields were more correlated with grains/unit area than with grain weight (Table 4). Grains/unit area is composed of grains/ear and ears/unit area. Variation in grain yield was unrelated (1989), weakly (1990) and even negatively (1991) related to ears/unit area. Our results highlight the importance of grain weight and particularly the number of grains per ear. Assuming that grains/ear can be increased, then the increased demand for assimilates must be considered. Variation in harvest index was associated more with grain weight than with number of grains. However, it is questionable whether increasing the number of grains would give greater harvest index and yield. More research is needed to determine if genetic variability for grains/ear can be exploited for grain yield improvement.

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Effects of Seeding Date on Yield and Yield Components of Bread Wheat

تأثير موعد الزراعة على الغلة ومكوناتها في القمح الطري

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Abstract

Two experiments, one each at Holetta and Kulumsa, Ethiopia, were conducted in 1989 to determine the effect of seeding date (early, normal, late) on biomass, grain yield and yield components of bread wheat (*Triticum aestivum* L. subsp. *aestivum*) genotypes differing in maturity, and to assess if some flexibility is possible in seeding date. Seeding-date effects were significant for biomass, grain yield, number of grains/spike and 1000-grain weight at both locations. Variation in grain yield among seeding dates was significantly associated with variation in 1000-grain weight and number of grains/spike. Genotypes responded differently to seeding dates as indicated by significant seeding date × genotype interactions for biomass, grain yield, number of grains/spike and 1000-grain weight at one or both locations. Significantly depressed grain yield in early seeding at Holetta coincided with increased incidence of leaf blotch disease (*Septoria tritici* Rob. in Desm.) on susceptible genotypes, and grain-yield depression in late seeding at Kulumsa was associated with desiccating dry wind during the grain-filling period. Depending on environmental conditions, increased flexibility in seeding dates with selected genotypes may be possible for wheat growers towards late seeding (mid-July) at Holetta and early seeding (third week of June) at Kulumsa. Further studies, including more seeding dates, combined with other management practices are needed to confirm these results.

الملخص

أجريت تجربتان، إحداهما في هوليتا والأخرى في كولومسا بإثيوبيا، في 1989 لتحديد تأثير موعد الزراعة (مبكر، عادي، متأخر) على الكتلة الحيوية، الغلة الحبية ومكونات الغلة لطرز وراثية من القمح الطري (*Triticum aestivum* L. subsp. *aestivum*) متباينة في النضج، ولتقييم فيما إذا كانت هناك بعض المرونة في موعد الزراعة. وكانت تأثيرات موعد الزراعة كبيرة بالنسبة للكتلة الحيوية، الغلة الحبية، عدد الحبات/السنبلة ووزن الألف حبة في كلا الموقعين. وقد اقترن التباين في الغلة الحبية بين مواعيد الزراعة معنوياً بالتباين في وزن الألف حبة وعدد الحبات/السنبلة. واستجابت الطرز الوراثية على نحو مختلف لمواعيد الزراعة حسبما أشارت التفاعلات الهامة بين موعد الزراعة X الطرار الوراثي بالنسبة للكتلة الحيوية، الغلة الحبية، عدد الحبات/السنبلة ووزن الألف حبة في موقع واحد أو في كلا الموقعين. وتزامنت الغلة الحبية التي انخفضت بشكل كبير في الزراعة المبكرة في هوليتا مع تزايد انتشار مرض التبقع السبيتوري (*Septoria tritici*) على الطرز الوراثية الحساسة، كما اقترن انخفاض الغلة الحبية في الزراعة المتأخرة في كولومسا بهبوب رياح جافة مُجفِفة خلال طور امتلاء الحب. واستناداً إلى الظروف البيئية، قد يتاح لمزارعي القمح مزيد من المرونة في مواعيد الزراعة مع استخدام طرز وراثية مختارة من أجل الزراعة المتأخرة (منتصف تموز/يوليو) في هوليتا، والزراعة المبكرة (الأسبوع الثالث من حزيران/يونيو) في كولومسا. وهناك حاجة إلى مزيد من الدراسات التي تشمل مواعيد زراعة أكثر إلى جانب معاملات زراعية أخرى وذلك للتأكد من هذه النتائج.

Key words: *Triticum aestivum*; soft wheat; sowing date; yield components; yields; biomass; Ethiopia.

Introduction

In Ethiopia, wheat production is exclusively under rainfed conditions. Bread wheat, which does best on well-drained soils, has a wide adaptability and high yield potential (Getinet 1988; Hailu 1991). However, its average yield is generally low, which is partly attributed to sub-optimal cultural practices. One of the production factors that plays a major role in increasing yield of wheat is time of seeding (Getinet 1985; Tanner et al. 1991). Many studies have shown that the inherent potential of a crop can be exploited when it is properly exposed to its suitable growth environment (Anderson and Smith 1990; Briggs and Aytenfisu 1979; Ciha 1983). In southwestern Australia, yield advantages of semidwarf wheat genotypes depend on seeding earlier (in May and early June) than the common period (Anderson and Smith 1990). At

Ginchi, significantly increased yields of bread and durum wheat genotypes were obtained when seeded early in late June and late in early August, respectively (Jemal 1985). Late seeding beyond a certain critical period reduced the number of productive tillers and grains/spike, but increased grain weight (Anderson and Smith 1990; Ciha 1983; Jemal 1985). Seeding of wheat earlier than the common period also results in significantly depressed yields due to increased incidence of leaf blotch (*Septoria tritici*) (Anderson and Smith 1990; Hailu et al. 1988). For increasing yield of wheat, several workers have emphasized the exploitation of favorable seeding date × genotype interactions (Anderson and Smith 1990; Briggs and Aytenfisu 1979; Ciha 1983).

At Holetta and Kulumsa, seeding of wheat is restricted to the period from late June to early July (Getinet 1985, 1988; Hailu et al. 1988; Tanner et al. 1991). This is due to increased incidence of leaf blotch if wheat is seeded early in June at Holetta, and to moisture stress and desiccating dry winds during grain-filling if wheat is seeded late in July and August at Kulumsa (Getinet 1988; Hailu et al. 1988; Tanner et al. 1991). A wide range of seeding dates may be helpful to wheat growers in Ethiopia. This flexibility may be possible if wheat genotypes that differ in maturity are properly adjusted to their suitable growth environment. Although studies on medium- to long-maturity genotypes provided the direction in which date of seeding likely affects wheat yield, they have not produced conclusive results. Neither the optimum date for seeding of short-, medium- and long-maturing genotypes nor the underlying changes in plant attributes have been investigated. Therefore, these experiments were conducted to determine the effect of seeding date on biomass, grain yield and yield components of bread wheat genotypes differing in maturity, and to determine if a greater flexibility in seeding date is possible under Holetta and Kulumsa conditions.

Material and Methods

Two experiments were conducted in 1989, one on reddish brown soil at Holetta, Ethiopia, and the other on dark grey soil at Kulumsa, Ethiopia. Experiments were replicated three times and laid out in a split-plot design using three seeding dates as main-plot and six bread wheat genotypes as sub-plot treatments. Seeding dates, designated as E (early), N (normal) and L (late), were 15 June, 30 June and 15 July at Holetta, and 23 June, 8 July and 23 July at Kulumsa. Genotypes used were those with relatively short (Dereselign and HAR 715†), medium (Enkoy and K6295-4a) and long (Romany B.C. and Dashen†) maturity. A seed rate of 125 kg/ha and fertilizer rates of 46 kg N and 26.6 kg P/ha were applied at planting in rows spaced 20 cm apart.

Data were collected on biomass and grain yields (g/10 m^2), number of productive tillers/m^2, grains/spike and 1000-grain weight. The yields were taken at 12.5% moisture level and converted to tonnes/ha. All variables measured on a plot basis were subjected to analysis of variance. Combined analysis was not performed due to heterogeneous error terms between locations. Simple correlations were determined between grain yield and yield components, using the genotype mean values of each seeding date at both locations.

Results and Discussion

The amount of rainfall, minimum temperature and wind velocity during the crop-growing season varied widely over the two locations (Fig. 1). In 1989, the early-seeding period at Holetta was drier than that at Kulumsa. During grain-filling (September onwards), the crops received below-average rains and minimum temperature at Holetta, while at Kulumsa rainfall and wind velocity were above average for most of the season. At Holetta, severe leaf blotch incidence was observed in early-seeded wheat (data not shown). Genotypes grown at Holetta produced higher average grain yield (4.5 t/ha) and took longer to reach physiological maturity (130 days) than those at Kulumsa (3.2 t/ha and 114 days, respectively). The higher grain yield at Holetta was due to the favorable effect of low wind velocity and longer, cool growing season, which enhanced dry-matter accumulation in grains. Midmore et al. (1984) report higher yields for several bread wheat genotypes grown at cooler sites in Central Mexico.

Seeding dates significantly affected biomass and grain yield at both locations (Table 1). As seeding was delayed, mean grain yields of genotypes significantly increased at Holetta and decreased at Kulumsa. Biomass yields were significantly higher for normal and late seedings at Holetta and for early and normal seedings at Kulumsa. The effect of seeding date on the number of grains/spike and 1000-grain weight was significant

† Semidwarf genotypes.

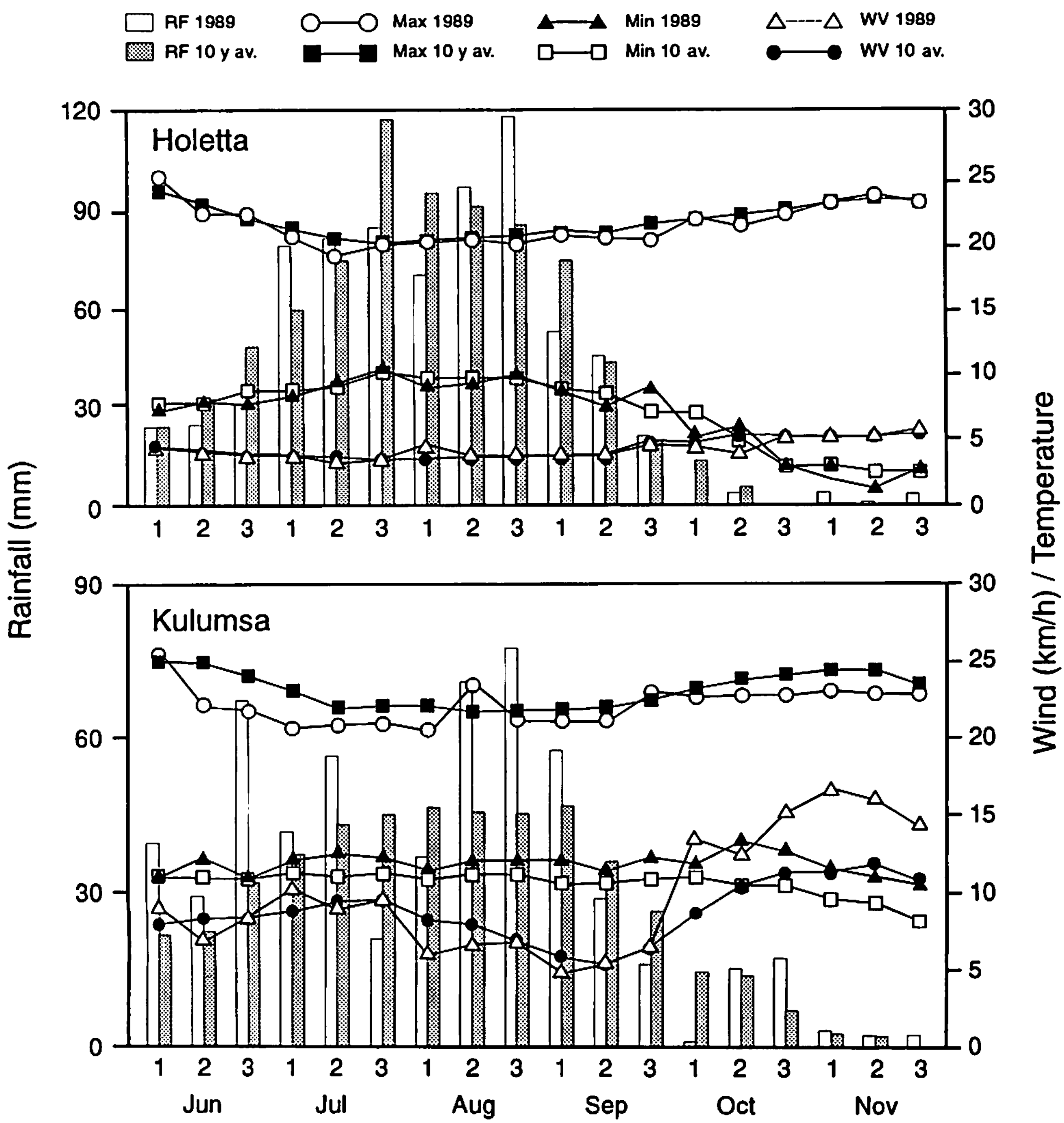

Figure 1. Ten-day rainfall (mm), max. and min. temperature (°C) and wind velocity (km/h) during crop growing season at Holetta (a) and Kulumsa (b).

Table 1. Mean biomass and grain yield of six bread wheat genotypes (G) as affected by seeding dates (S) at two locations in Ethiopia, 1989.

Genotype	Holetta								Kulumsa							
	Biomass yield (t/ha)				Grain yield (t/ha)				Biomass yield (t/ha)				Grain yield (t/ha)			
	E†	N	L	Mean	E	N	L	Mean	E	N	L	Mean	E	N	L	Mean
Dereselign	9.6	11.5	13.9	11.7	2.1	3.5	4.9	3.5	13.3	15.2	14.9	14.5	2.8	3.7	3.0	3.2
HAR 715	8.4	10.0	12.6	10.3	2.6	3.6	5.9	4.0	12.2	13.9	12.0	12.7	3.8	4.4	3.2	3.8
Enkoy	11.9	13.3	15.2	13.5	4.1	4.9	5.1	4.7	14.7	15.3	9.2	13.1	4.1	3.2	1.8	3.0
K6295-4a	11.8	14.5	16.0	14.1	3.5	4.5	4.8	4.3	15.4	15.6	11.5	14.2	4.3	3.5	2.4	3.4
Romany B.C.	16.6	16.1	14.9	15.9	5.4	4.3	3.9	4.5	15.5	14.9	8.3	12.9	3.2	3.0	1.5	2.6
Dashen	13.1	16.8	16.6	15.5	4.6	7.0	6.3	6.0	14.2	11.1	10.6	12.0	4.1	3.3	2.2	3.2
Mean	11.9	13.7	14.9		3.7	4.7	5.2		14.2	14.3	14.1		3.7	3.5	2.4	
$LSD_{0.05}$																
S				1.31				0.35				1.14				0.17
G				0.96				0.34				0.24				0.24
S × G				1.98				0.61				1.27				0.42
CV (%)				7.4				7.9				5.3				8.0

† E, N and L represent early, normal and late seeding dates, respectively.

Table 2. Mean number of grains per spike and 1000-grain weight of six bread wheat genotypes (G) as affected by seeding dates (S) at two locations in Ethiopia, 1989.

Genotype	Holetta								Kulumsa							
	Grains/spike				1000-grain weight (g)				Grains/spike				1000-grain weight (g)			
	E†	N	L	Mean	E	N	L	Mean	E	N	L	Mean	E	N	L	Mean
Dereselign	20	31	31	27	29.9	31.9	35.8	32.5	23	26	23	24	34.1	34.3	33.0	33.8
HAR 715	23	33	32	29	32.4	36.1	39.7	36.1	33	37	31	34	35.2	34.8	33.6	34.5
Enkoy	27	33	29	30	35.6	36.1	35.6	35.8	26	24	21	24	33.5	33.3	29.1	32.6
K6295-4a	21	29	30	27	34.3	37.5	38.2	36.7	27	24	25	25	35.6	35.1	31.5	34.1
Romany B.C.	25	32	35	31	39.9	42.3	35.3	39.2	32	25	19	25	38.6	33.4	23.6	31.9
Dashen	42	46	44	44	35.0	39.7	37.5	37.4	39	31	25	32	36.9	33.5	28.2	32.9
Mean	26	34	34		34.5	37.3	37.1		30	28	24		35.6	34.1	29.8	
$LSD_{0.05}$ S				3.58				0.64				3.31				1.57
G				2.57				1.07				2.74				1.33
S × G				n.s.				1.84				4.75				2.31
CV (%)				8.53				3.08				10.47				4.16

† E, N and L represent early, normal and late seeding dates, respectively.
n.s. = Statistically non-significant.

(Table 2). However, the number of productive tillers/m², which is an important component of yield (Fischer 1975), was not significantly affected by seeding date as reported by Midmore et al. (1984). The results obtained for grain weight at Holetta agree with those of Jemal (1985) at Ginchi, and those for number of grains/spike at Kulumsa agree with those of Anderson and Smith (1990) in southwestern Australia and Midmore et al. (1984) in Central Mexico. Variation in grain yield within seeding dates was associated with variation in number of grains/spike and 1000-grain weight as indicated by significant positive correlations in late seeding at Kulumsa and early seeding (with grain weight) and normal seeding (with grains/spike) at Holetta (Table 3). However, there was no significant correlation between grain yield and number of productive tillers/m². Results reported by Midmore et al. (1984) indicate that variation in grain yield among seeding dates was closely associated with variation in number of grains/m². Reduced grain yields corresponding with a significant reduction in number of grains and grain weight in early seeding at Holetta were attributed to increased leaf blotch disease as reported by Hailu et al. (1988) and reviewed by Tanner et al. (1991), while those in late seeding at Kulumsa were attributed to the desiccating dry wind.

Table 3. Simple correlation coefficients between grain yield and yield components at different seeding dates in Ethiopia, 1989.

Seeding date	Component	Grain yield	
		Holetta	Kulumsa
Early	Productive tillers/m²	-0.185	-0.066
	1000-grain weight	0.952**	-0.093
	No. grains/spike	0.538	0.338
Normal	Productive tillers/m²	-0.550	0.053
	1000-grain weight	0.266	0.719
	No. grains/spike	0.875*	0.763
Late	Productive tillers/m²	0.029	0.320
	1000-grain weight	0.628	0.917*
	No. grains/spike	0.472	0.808*

*, ** Correlation coefficent was signicantly different from zero at P=0.05 and 0.01, respectively (n=6).

Highly significant differences among genotypes existed for all variables at one or both locations, except for the number of productive tillers/m² (Table 1 and 2). Semidwarf genotypes produced higher grain yields than normal genotypes at both locations. At Holetta, Dashen had significantly higher grain yields and more grains/spike, but fewer productive tillers. At Kulumsa, HAR 715 had significantly higher grain yields, more grains/spike and heavier grains. Biomass yields were significantly superior for Romany B.C. and Dashen at Holetta, and for Dereselign and K6295-4a at Kulumsa. Generally, Dashen and Romany B.C. were best performers at Holetta, and Dereselign and HAR 715 were best at Kulumsa. These results confirm the previous recommendations made by Getinet (1988) for these genotypes.

Significant seeding date by genotype (S × G) interactions were obtained for biomass, grain yield and 1000-grain weight at both locations, and for grains/spike at Kulumsa (Table 1 and 2). This indicated that short-maturing genotypes (Dereselign and HAR 715) had the yield advantage in late seeding, and long-maturing genotypes (Romany B.C. and Dashen) had the advantage in early seeding. With each delay in seeding, grain yields were significantly increased for Dereselign and HAR 715 at Holetta, and decreased for Romany B.C. and Dashen at Kulumsa. This indicates that flexibility in seeding date can be obtained by further extending towards late seeding at Holetta and early seeding at Kulumsa. Significant S × G interaction for grain yield and yield components with spring wheat at different locations has been reported by various workers (Anderson and Smith 1990; Briggs and Aytenfisu 1979; Ciha 1983). The existence of S × G interactions, particularly for yield, indicated that new as well as existing genotypes that differ in maturity need to be tested under various seeding dates and production practices at both locations

Results from these preliminary experiments indicate that: (a) genotypes responded differently to seeding dates; (b) changes in number of grains/spike and grain weight were the major contributors to yield differences among seeding dates; (c) a wider flexibility in seeding date with selected genotypes may be possible towards late seeding (mid-July) at Holetta and early seeding (third week of June) at Kulumsa; and (d) increased incidence of leaf blotch may preclude seeding of susceptible genotypes early in June at Holetta, while desiccating dry wind during the grain-filling period may prevent seeding of long-season genotypes late (third week of July) at Kulumsa.

Further seeding-date studies, including more dates, combined with other management practices such as fertilization, disease and weed control and seed rates should be conducted at both locations.

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Varietal Response of Wheat to Water Stress at Different Growth Stages. III. Effect on Grain Yield, Straw Yield, Harvest Index and Protein Content in Grain†

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Abstract

Three cultivars of wheat (*Triticum aestivum* L. subsp. *aestivum* cv Pak 81, Punjab 85 and Kohinoor) were subjected to mild water stress (-10 bars on-leaf-water potential basis) at tillering, jointing, boot and

استجابة أصناف القمح لإجهاد الماء في مختلف أطوار النمو

III. التأثير على الغلة الحبية، غلة التبن، دليل الحصاد ومحتوى البروتين في الحب

الملخص

عُرِّضت ثلاثة أصناف من القمح (*Triticum aestivum* L. subsp. *aestivum*) لإجهاد مائي منخفض (–10 باروميتر على أساس طاقة الورقة المختزنة من الماء) في عدة أطوار من النمو، الإشطاء، التمفصل، الحبل والإزهار. وتم تحديد طاقة الأوراق المركزية من المياه المختزنة على أيام متناوبة باستخدام 'قنبلة ضغط' حتى يتحقق المستوى المطلوب وهو – 10 باروميتر. وفي هذا الطور، أُنهي دلاء إجهاد الماء بإضافة 7,5 هكتار سنتيمتر من الماء بواسطة معيّرة. وتمت حماية القطع التجريبية، المعرضة للإجهاد، من المطر بغطاء من البوليثلين الذي يوضع عند الضرورة فوق إطار حديدي. لقد انخفضت الغلة الحبية بشكل كبير نتيجة إجهاد الماء في جميع

† Part of PhD thesis submitted to the University of Agriculture, Faisalabad, Pakistan.

anthesis growth stages. Water potential of the central leaves was determined on alternate days using a Pressure Bomb until the desired level of -10 bars was achieved. At this stage water stress was terminated by applying 7.5 cm/ha water by calibrated buckets. Stressed plots were protected from rain by polyethylene sheets placed over iron frames when needed. Grain yield of wheat was significantly reduced by water stress at all stages of growth. However, maximum adverse effect was noted when stress occurred at anthesis. Among cultivars, Pak 81 was highest yielding, followed by Punjab 85. Interaction between cultivars and water-stress treatments was also significant. Kohinoor was the most sensitive cultivar to water stress, particularly stress at anthesis. Straw yield was reduced by water stress only when it occurred at jointing. Harvest index was significantly reduced by all stress treatments. Grain protein content was drastically increased by water stress, especially stress at anthesis. Pak 81 and Punjab 85 had significantly more protein content than Kohinoor. However, maximum grain protein content was recorded in Punjab 85 and Kohinoor when stressed at anthesis, but the minimum was recorded in the control.

Key words: *Triticum aestivum*; soft wheat; varieties; drought stress; developmental stages; grain; yields; straw; harvest index; protein content; Pakistan.

أطوار النمو، إلا أنه لوحظ أقصى تأثير معاكس عند حدوث الإجهاد في طور الإزهار. ومن بين الأصناف كان باك 81 أكثرها غلة، تلاه بنجاب 85. كما كان التفاعل بين الأصناف ومعاملات إجهاد الماء على جانب كبير من الأهمية. وكان كوهينور أكثر الأصناف حساسية لإجهاد الماء، لاسيما للإجهاد في طور الإزهار. وقد انخفضت غلة التبن فقط عند حدوث الإجهاد في طور التمفصل.

أما دليل الحصاد فقد انخفض بشكل كبير نتيجة جميع معاملات الإجهاد، في حين تزايد محتوى الحب من البروتين بشدة بالإجهاد المائي وخاصة عند الإجهاد في طور الإزهار علماً أن محتوى باك 81 وبنجاب 85 من البروتين أكثر بكثير منه في كوهينور. غير أنه سُجل أقصى محتوى بروتيني للحب في بنجاب 85 وكوهينور عندما تعرضا للإجهاد في طور الإزهار، في حين سُجِل أدنى محتوى بروتين للحب في الشاهد.

Introduction

Soil moisture levels are rarely optimal during the growing season of a crop. In semi-arid regions, irrigation water is often in short supply. About a third of the world's arable land suffers from some water stress and most of the remaining area is subject to drought (Kramer 1980). Such a situation exists in the wheat-growing areas of Pakistan. In these areas, the topsoil dries out (due to lack of irrigation or rainfall) by the end of winter, when the wheat crop starts growing rapidly. When this occurs, nutrient uptake and yield are likely to be lower than if the topsoil had remained wet until near maturity. It is, therefore, essential to determine the optimum growth stage for applying supplemental irrigation to maximize wheat yields. Salim et al. (1965) suggest that the most critical period for most small grains is during heading. Day and Intalap (1970) found that, in spring wheat grown in winter under irrigation, the jointing stage was a critical period for moisture. Salter and Goode (1967) conclude that wheat plants appear to be most drought tolerant at tillering. They further report that when Marquis spring wheat wilted at tillering, it yielded more grain than non-stressed plants. However, if it wilted at a later stage (e.g. at shooting, earing or when grain was milk-ripe), grain yield was greatly reduced.

Black (1967) found two periods in the life of a wheat plant when it is most susceptible to water and nutrient stresses: immediately before ear emergence (when number of fertile florets/spikelet is determined); and, less pronounced, at jointing (when the supply of available water and food materials to the plant determines whether the tillers survive). Kezer and Robertson (1927) conclude that early irrigation at germination or tillering increased the straw yield to a greater extent than the grain yield, and also reduced the grain quality. Irrigation as late as the dough stage had little effect on either grain or straw yield. Aspinall et al. (1964) also noticed the suppressing effect of water stress on cereals at tillering which, however, could be stimulated with renewed water supply. Duwayri (1984) found that water stress reduced grain and straw yield. However, tiller initiation and emergence were less sensitive to water stress than the subsequent vegetative growth of the tillers (Davidson and Chevalier 1987). Simmon (1987) observed that grain N and P concentrations decreased with irrigation, but straw P and K concentrations increased. Tisdale et al. (1985) report that protein content of the grain is frequently influenced by the amount of available water; higher percentages of protein are generally associated with low levels of extractable soil moisture as demonstrated in barley. Hanson and Hitz (1983) observed that the increase in nitrate concentration under water stress could be due to inhibition of nitrate reductase activity. They also report that this compound may work as an osmoticant. Total reduced nitrogen was increased in drought-stressed plants. Cultivars with high harvest index are efficient in converting their dry matter into grain yield (Anonymous 1983).

The present study was designed to find the effect of drought stress on grain and straw yields, harvest index and grain protein content of wheat under the climatic conditions of Faisalabad (Pakistan).

Material and Methods

Wheat response to water stress at different plant developmental stages was investigated at the Agronomic Research Area, University of Agriculture, Faisalabad during 1988/89 and 1989/90. Soil was sandy clay-loam having on an average 520 mg N/kg, 7.4 mg P_2O_5/kg and 96 mg K_2O/kg (Table 1). Meteorological data for the growing period are presented in Table 2. Three wheat cultivars, Pak 81 (V1), Punjab 85 (V2) and Kohinoor (V3), were subjected to reduced water level at four growth stages, namely tillering (S1), jointing (S2), boot (S3) and anthesis (S4). A control treatment of no irrigation (S5) was also included. The experiment was laid out in split-plot design with four replications, with stress treatments in main plots and varieties in sub-plots. Net plot size was 1.5 × 2 m. Six wheat rows at a spacing of 25 cm were sown in each plot.

Table 1. Physico-chemical analysis of experimental topsoil (30 cm), Faisalabad.

Determination	1988/89	1989/90
Mechanical analysis (%)		
Sand	65.5	65.1
Silt	14.6	14.9
Clay	20.1	20.6
Chemical analysis		
pH	8.05	8.00
ECe (ds/m)	2.9	2.79
OM (%)	0.50	0.59
Total N (%)	0.046	0.058
Available P (mg/kg)	7.1	7.7
Available K (mg/kg)	90	102

The crop was planted on a well-prepared seedbed on 23 and 18 November in 1988 and 1989, respectively. A basal fertilizer dose of 75 kg N and 75 kg P/ha was applied at sowing. Normal seed rate of 100 kg/ha was used. To avoid possible seepage of irrigation water from one plot to another, a drain (1 m wide) was dug around each plot. Stress treatments were protected from rain water by polyethylene sheets placed over iron frames. Water stress of up to -10 bars was created at each stage of plant development by withholding irrigation and rain water while other treatments were irrigated by applying irrigation water at 7.5 cm/ha. For determining leaf water potential (LWP) of -10 bars in the respective treatments, leaf samples were collected in a thermos bottle at dawn and the LWP was measured by using the Pressure Bomb method (Swanson 1975). This was repeated on alternate days until the LWP of -10 bars was obtained in the middle leaves. At this point, water stress was terminated by applying irrigation water of 7.5 cm/ha. Each plot was irrigated by calibrated buckets. Data on grain yield, straw yield, harvest index and protein content were also recorded and statistically analyzed.

Results and Discussion

Grain Yield

Grain yield was significantly affected by water stress at different growth stages during both years (Table 3). In 1988/89, although there were significant differences among all the water-stress treatments, grain yield was decreased most by stress at anthesis stage and was 2.927 t/ha. Jointing was the next sensitive stage to water stress, followed by boot stage. Water stress applied at jointing gave a grain yield of 4.123 t/ha compared with 4.490 t/ha with stress at boot stage. Low grain yield under stress at jointing stage was due to the reduced number of spike-bearing tillers per unit area. The same trend was noted in 1989/90. However, the difference between stress given at jointing and boot stages was non-significant. On the basis of two years data, water stress at different growth stages significantly decreased the final grain yield compared with the control. At anthesis, yield decreased by 40%, compared with 20, 16 and 6% decreases for stress applied at jointing, boot and tillering stages, respectively. These results indicate that anthesis was the most sensitive stage to water stress, resulting in maximum reduction in grain yield. This is attributed to improper grain formation and development because seed formation and weight are highly sensitive to low moisture during anthe-

Table 2. Meteorological data for the crop-growing period, Faisalabad, 1988/89–1989/90.

Month	1988/89				1989/99			
	Temp (°C)		RH (%)	Rain (mm)	Temp (°C)		RH (%)	Rain (mm)
	Max	Min			Max	Min		
Nov	27.9	11.6	76	0	27.9	12.1	70.0	0
Dec	22.4	7.4	80	21.9	21.4	8.6	79.0	25.2
Jan	19.5	5.3	83	30.0	21.3	7.9	81.5	20.2
Feb	22.2	6.8	72	2.8	21.7	9.2	81.0	51.7
Mar	25.9	12.8	69	0.7	24.9	11.9	70.0	10.0
Apr	30.0	16.1	51	1.1	34.2	17.7	51.9	16.0
Total				56.5				123.1

Source: Department of Meteorology, University of Agriculture, Faisalabad.

sis and dough stage (Arnon 1972). These results conform with those of Black (1967), Salim et al. (1965), and Salter and Goode (1967). Day and Intalap (1970) found that spring wheat grown in winter under irrigated conditions was most sensitive to moisture stress at jointing stage.

There were significant differences in grain yield for the three cultivars under study during both years (Table 3). In 1988/89, Pak 81 produced the highest grain yield (4.596 t/ha), compared with Punjab 85 and Kohinoor which gave 4.404 and 4.118 t/ha, respectively. By contrast, in 1989/90 although Pak 81 gave significantly higher grain yield (4.850 t/ha) than Kohinoor (4.585 t/ha), it was equal to Punjab 85 (4.838 t/ha). In the two-year average data, the cultivars all differed significantly from one another. Highest grain yield of 4.723 t/ha was recorded for Pak 81, compared with 4.621 and 4.338 t/ha for Punjab 85 and Kohinoor, respectively. This indicates that the inherent yield potential of Pak 81 is higher than that of Punjab 85 which, in turn, is higher than that of Kohinoor. Lower yield potential of Kohinoor could be due to its awnless spikes, the effect of which is known (Shmat'Ko et al. 1982). Similar results are reported by Anonymous (1989).

Interaction between cultivars and water stress was non-significant during both years. However, the two-years average data exhibited significant interaction. Water stress at anthesis drastically decreased the grain yield of all the cultivars. Kohinoor appeared to be the most sensitive to water stress at this stage; Punjab 85 and Pak 81 were statistically similar to each other. The data also indicated that at each stress stage Pak 81 significantly out-yielded the other two varieties.

Straw yield

In 1988/89 straw yield was not affected by water stress; however, in 1989/90, it was significantly influenced by water stress at different growth stages (Table 4). There was no significant difference in the straw yield obtained from anthesis stress treatment and from the control. Stress imposed at jointing stage produced minimum straw yield of 7.946 t/ha, compared with 8.270 and 8.676 t/ha when stressed at tillering and boot stage, respectively. Two-years average data revealed that water stress significantly affected straw yield. Stress given at jointing significantly reduced straw compared with all other treatments, which were statistically equal to each other. Reduced straw yield in jointing-stage stress was attributed to less vegetative growth as a result of limited water supply. Stress at jointing stage may also be detrimental for the growth of later-emerged tillers which consequently do not contribute to grain/straw yield (Davidson and Chevalier 1987). These results are in agreement with those of Kezer and Robertson (1927) and Duwayri (1984). Straw yield was not affected by cultivars (Table 4); however, straw yield was higher in 1989/90 than in 1988/89, probably due to weather conditions. Interaction between stress and cultivars was significant only during 1989/90 (Table 4). The highest straw yield of 9.025 t/ha was from Pak 81 stressed at anthesis (S4 V1); the minimum of 7.512 t/ha was from Pak 81 stressed at jointing.

Harvest Index

Harvest index (HI) indicates the ability of a plant to partition total dry matter into economic yield. In 1988/89, water stress significantly affected HI (Table 5). Water stress at anthesis gave the lowest HI (25.43%) followed

Table 3. Grain yield (t/ha) as affected by cultivars and water stress at different growth stages of wheat, Faisalabad.†

Treatment	1988/89	1989/90	Mean
Stress stage (S)			
Tillering (S1)	5.057 b	5.197 b	5.127 b
Jointing (S2)	4.123 d	4.587 c	4.355 d
Boot (S3)	4.490 c	4.693 c	4.592 c
Anthesis (S4)	2.927 e	3.643 d	3.285 e
Control (S5)	5.267 a	5.623 a	5.445 a
$LSD_{0.05}$	0.014	0.178	0.090
Cultivar (V)			
Pak 81 (V1)	4.596 a	4.850 a	4.723
Punjab 85 (V2)	4.404 b	4.838 a	4.621 b
Kohinoor (V3)	4.118 c	4.558 b	4.338 c
$LSD_{0.05}$	0.007	0.118	0.069
Interaction (S × V)			
S1 V1	5.32	5.44	5.380 b
S1 V2	5.06	5.27	5.160 c
S1 V3	4.79	4.88	4.835 d
S2 V1	4.36	4.72	4.540 ef
S2 V2	4.10	4.58	4.340 gh
S2 V3	3.91	4.46	4.185 h
S3 V1	4.67	4.68	4.675 e
S3 V2	4.58	4.77	4.675 e
S3 V3	4.22	4.63	4.425 fg
S4 V1	3.10	3.59	3.345 i
S4 V2	2.99	3.88	3.425 i
S4 V3	2.71	3.46	3.085 j
S5 V1	5.53	5.82	5.675 a
S5 V2	5.31	5.69	5.500 b
S5 V3	4.96	5.36	5.160 c
$LSD_{0.05}$	n.s.	n.s.	0.155

† Means followed by different letters in a column are significantly different at $P \leq 0.05$.
n.s. = non-significant.

by water stress at jointing and boot stages which were statistically similar to each other (34.27 and 35.18%, respectively). A similar trend was observed in 1989/90, with the exception that stress at tillering did not have significantly different effects from the control. The average of the two-years data indicated that HI decreased significantly over the control when plants were stressed at any growth stage. Water stress at anthesis resulted in lowest HI of 26.69%, compared with 34.43 and 34.91% for stress applied at boot and jointing, respectively. We suggest that anthesis is the most sensitive stage to low water stress and an adequate amount of water must be supplied to the wheat crop at anthesis to achieve maximum grain yield. These findings concur with those reported by Aspinall et al. (1964) and Arnon (1972).

Harvest index was also significantly influenced by cultivars during both years (Table 5). In 1988/89, Pak 81 gave significantly highest HI (35.36%). By contrast, in 1989/90, highest HI was given by Pak 81 (34.64%), but this was statistically equal to that of Punjab 85 (34.56%). Harvest index of Kohinoor was minimum during this year. Two-year average data indicated significant differences among cultivars. Pak 81 exhibited significantly higher HI (35.00%) than Punjab 85 (34.43%) and Kohinoor (33.20%). This indicates that the ability to partition dry matter into grain yield is highest in Pak 81, followed by Punjab 85 and Kohinoor. Similar results are reported by Anonymous (1983). Interaction of water stress and cultivars was also significant during both years (Table 5). In 1988/89, lowest HI was recorded in all varieties subjected to water stress at anthesis. A similar trend was noted in 1989/90. On the basis of two-years average data, Kohinoor when stressed at anthesis (S4 V3) gave the lowest HI (25.72%), and highest (38.67%) was from Pak 81 without water stress (control). The data further indicate that Pak 81 subjected to low water stress at tillering (S1 V1) did not suffer significantly and maintained normal HI compared with the other two cultivars.

Protein content in grain

Grain protein content was also influenced by water stress during both years (Table 6). In 1988/89, highest grain protein concentration (14.23%) was recorded when water stress was imposed at anthesis, followed by boot, jointing and tillering which gave on average 13.70, 13.45 and 13.11% grain protein content, respectively. The lowest grain protein (12.70%) was obtained in the control. A similar trend occurred in 1989/90. An increase in the total reduced nitrogen in drought-stressed plants is also

Table 4. Straw yield (t/ha) as affected by cultivars and water stress at different growth stages of wheat, Faisalabad.†

Treatment	1988/89	1989/90	Mean
Stress stage (S)			
Tillering (S1)	8.911	8.675 c	8.742 a
Jointing (S2)	8.311	7.946 d	8.128 b
Boot (S3)	9.257	8.270 b	8.763 a
Anthesis (S4)	9.374	8.590 a	8.982 a
Control (S5)	9.550	8.110 a	8.830 a
$LSD_{0.05}$	n.s.	0.031	0.468
Cultivar (V)			
Pak 81 (V1)	9.075	8.355	8.715
Punjab 85 (V2)	9.428	8.354	8.741
Kohinoor (V3)	9.037	8.234	8.636
$LSD_{0.05}$	n.s.	n.s.	n.s.
Interaction (S × V)			
S1 V1	9.255	8.710 c	8.982
S1 V2	9.140	8.350 ef	8.745
S1 V3	8.337	8.912 b	8.625
S2 V1	8.280	7.512 i	7.896
S2 V2	8.482	8.405 de	8.444
S2 V3	8.170	7.920 j	8.045
S3 V1	9.130	8.190 i	8.660
S3 V2	8.730	8.350 ef	8.540
S3 V3	9.910	8.270 gh	9.090
S4 V1	9.032	9.025 a	9.029
S4 V2	9.680	8.425 d	9.052
S4 V3	9.410	8.320 gh	8.865
S5 V1	9.680	8.340 f	9.010
S5 V2	9.610	8.240 hi	8.925
S5 V3	9.360	7.750 k	8.555
$LSD_{0.05}$	n.s.	0.057	n.s.

† Means followed by different letters in a column are significantly different at $P \leq 0.05$.
n.s. = non-significant.

reported by Hanson and Hitz (1983). Similar results are reported by Tisdale et al. (1985) and Simmon (1987).

Grain protein content was significantly affected by cultivars in both years (Table 6). In 1988/89, the highest protein content was recorded in Pak 81; Punjab 85 and Kohinoor were equal. However, in 1989/90, Pak 81 and Punjab 85 had similar protein content (13.74 and 13.75%, respectively). During this year Kohinoor had significantly lower grain protein content. Two-years average data showed a similar trend, i.e. lowest grain protein was recorded in Kohinoor, but Pak 81 and Punjab 85 were statistically equal.

Interaction between water stress and cultivars was significant in both years (Table 6). In 1988/89, minimum grain protein was recorded from Kohinoor under unstressed condition (S5 V3) which was significantly different from all other treatments. Highest grain protein was recorded in Punjab 85 and Kohinoor when stressed at anthesis (S4 V2 and S4 V3).

Conclusion

Water stress should be avoided in all the wheat cultivars studied here from jointing to anthesis in order to harvest maximum grain yield. Although different wheat cultivars reacted differently to water stress at various growth stages, anthesis was the most sensitive growth stage for all, despite an increase in straw yield. Water stress at this stage decreased the harvest index resulting in reduced grain yield. Pak 81 had highest HI while Kohinoor had the lowest. Grain protein content was increased by low water stress particularly at anthesis. Kohinoor had lower protein than Punjab 85 and Pak 81; however, when stressed at anthesis, grain protein of Pak 81 was significantly lower than that of the other cultivars.

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Table 5. Harvest index of wheat as affected by cultivars and water stress at different growth stages, Faisalabad.†

Treatment	1988/89	1989/90	Mean
Stress stage (S)			
Tillering (S1)	36.76 b	36.88 a	36.82 b
Jointing (S2)	34.27 c	35.56 b	34.91 c
Boot (S3)	35.18 bc	33.67 c	34.43 c
Anthesis (S4)	25.43 d	27.96 d	26.96 d
Control (S5)	39.33 a	37.05 a	38.19 a
$LSD_{0.05}$	1.73	0.76	0.89
Cultivar (V)			
Pak 81 (V1)	35.36 a	34.64 a	35.00 a
Punjab 85 (V2)	34.28 b	34.56 a	34.43 b
Kohinoor (V3)	32.93 c	33.47 b	33.20 c
$LSD_{0.05}$	0.85	0.72	0.54
Interaction (S × V)			
S1 V1	38.16 abc	37.06 ab	37.61 abc
S1 V2	37.88 abc	36.63 ab	37.26 bc
S1 V3	34.22 efg	36.96 a	35.59 de
S2 V1	36.78 bcd	36.32 ab	36.55 cd
S2 V2	32.95 g	35.60 bc	34.01 gh
S2 V3	33.06 g	35.30 bc	34.18 fg
S3 V1	36.32 cde	33.87 cd	35.10 efg
S3 V2	35.44 def	35.32 de	35.38 def
S3 V3	33.79 fg	31.82 e	32.81 h
S4 V1	25.77 h	28.40 fg	27.08 i
S4 V2	25.96 h	28.61 f	27.28 i
S4 V3	24.56 h	26.87 g	25.72 j
S5 V1	39.78 a	37.55 a	38.67 a
S5 V2	39.19 a	37.19 a	38.19 ab
S5 V3	39.00 ab	36.41 ab	37.71 a

† Means followed by different letters in a column are significantly different at $P \leq 0.05$.

Table 6. Grain protein content of wheat (%) as affected by cultivars and water stress at different growth stages, Faisalabad.†

Treatment	1988/89	1989/90	Mean
Stress stage (S)			
Tillering (S1)	13.11 d	13.37 c	13.24 d
Jointing (S2)	13.45 c	13.81 b	13.63 c
Boot (S3)	13.70 b	13.86 b	13.78 b
Anthesis (S4)	14.23 a	14.34 a	14.29 a
Control (S5)	12.70 e	12.92 d	12.81 e
$LSD_{0.05}$	0.15	0.16	0.10
Cultivar (V)			
Pak 81 (V1)	13.64 a	13.74 a	13.69 a
Punjab 85 (V2)	13.39 b	13.75 a	13.57 a
Kohinoor (V3)	13.28 b	13.51 b	13.39 b
$LSD_{0.05}$	0.15	0.16	0.16
Interaction (S × V)			
S1 V1	12.82 fg	13.33 g	13.07 fg
S1 V2	13.16 e	13.56 efg	13.36 de
S1 V3	13.34 de	13.22 gh	13.28 ef
S2 V1	13.22 de	13.96 cd	13.59 d
S2 V2	13.34 de	14.08 bcd	13.71 cd
S2 V3	13.79 b	13.39 fg	13.59 d
S3 V1	13.45 cd	13.99 cd	13.72 cd
S3 V2	13.96 b	13.74 def	13.85 bc
S3 V3	13.68 bc	13.85 cde	13.76 bcd
S4 V1	13.79 b	14.13 abc	13.96 b
S4 V2	14.30 a	14.42 ab	14.36 a
S4 V3	14.59 a	14.47 a	14.53 a
S5 V1	13.12 ef	13.28 gh	13.20 ef
S5 V2	12.20 g	12.93 hi	12.56 h
S5 V3	12.77 h	12.59 i	12.68 gh
$LSD_{0.05}$	0.33	0.36	0.24

† Means followed by different letters in a column are significantly different at $P \leq 0.05$.

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Effect of Water Stress on Carbon-14 Incorporation into Carbohydrates in Two Varieties of Durum Wheat

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Abstract

The effect of water stress on C-14 incorporation into carbohydrates in two cultivars of durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn. cv MBB 8037 and Capdur). The two cultivars were selected on the basis of growth analysis and differential responses to water stress.

The responses of the two varieties indicated the ability of these plants to increase the level of the major sugars found in wheat (sucrose, glucose, fructose) as well as a slight increase in inositol. MBB,

تأثير إجهاد الماء على إدماج الكاربون 14 في الكاربوهيدرات في صنفين من القمح القاسي

الملخص

تمت دراسة تأثير الإجهاد المائي على إدماج الكاربون 14 في الكاربوهيدرات في صنفين من القمح (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) هما، MBB 8037 وCapdur. وقد اختير الصنفان على أساس تحليل النمو والاستجابات المتغايرة للإجهاد المائي. وأشارت استجابات الصنفين إلى قدرة هذه النباتات على رفع مستوى المواد السكرية الرئيسية الموجودة في القمح (السكروز، غلوكوز، فركتوز) فضلاً عن رفع مستوى الإنوسيتول بشكل طفيف. أظهر الصنف MBB الذي وجد سابقاً أنه أكثر تحملاً للإجهاد المائي، زيادات أعلى وأكثر معنوية في المواد السكرية ولاسيما الغلوكوز مما هي في الصنف Capdur الأقل تحملاً. وقد يعكس الاندماج الأعلى للكاربون 14 في الكاربوهيدرات القابلة للانحلال في الإثانول (ESC) مقارنة بأجزاء الكاربوهيدرات غير القابلة للانحلال في الإثانول (EIC) تحت الإجهاد المائي

previously found to be more tolerant to water stress, showed higher and more significant increases in sugars, especially glucose, than the less-tolerant Capdur. The higher incorporation of C-14 into ethanol-soluble carbohydrate (ESC) compared with the ethanol-insoluble carbohydrate (EIC) fraction under water stress in both cultivars may reflect a shift in the flow of carbon towards producing low molecular weight and osmotically active compounds such as soluble sugars. Reduced synthesis of osmotically inactive large molecules such as starch under water stress may be indicated by relatively low level of C-14 in the EIC fraction.

Key words: *Triticum durum*; hard wheat; drought stress; carbon; carbohydrates; sugars; inositol.

في كلا الصنفين، تحولاً في تدفق الكاربون نحو إنتاج وزن جزيني متدني ومركبات حلولية فعالة من قبيل المواد السكرية الذوابة. وقد يشير المستوى المتدني نسبياً من الكاربون 14 في أجزاء EIC إلى التخليق المخفض للجزينات الكبيرة غير الفعالة حلولياً مثل النشا تحت الإجهاد المائي.

Introduction

Adequate water supply is a basic requirement for normal plant growth and development. Inadequate or interrupted water supply, as happens in semi-arid environments, often results in disruption of physiological processes, and consequent reduction in growth and yield. Most metabolic processes in plants are either directly or indirectly affected by water stress (Hanson and Hitz 1982; Hsiao et al. 1976). Changes in carbohydrates, especially sugars, may be important in providing some sort of resistance mechanism for plants, since tolerant and sensitive species are reported to differ in their carbohydrate composition under water stress (e.g. Drossopoulos et al. 1987). The importance of carbohydrate changes lies in their direct relationships with the physiological processes of photosynthesis, translocation and respiration. There are indications in the literature of the potential importance of these biochemical changes and their role in osmotic adjustment under water stress and salinity. Therefore, we investigated carbohydrates in two cultivars of durum wheat selected for their differences in growth responses to water stress. The source of sugar accumulation under water stress was investigated using radioactive CO_2.

Material and Methods

Two cultivars of durum wheat, Mohamed Ben Bachir 8037 (MBB) from Algeria and Capdur (Cap) from NIAB Cambridge, UK, were selected on the basis of growth analysis and differential responses to water stress.

Water-stress treatment was applied using the procedure of Raynal et al. (1985) starting with 24-day-old plants. The method consists of transferring lids bearing 5 of these replicate sets of plants to empty containers for different periods of time (once every 24 h), with periods of recovery in between (i.e. the rest of the 24-h period) when plants are again placed in solution. The control plants were left in the solution throughout the whole period of the experiment.

Carbohydrate analysis using GLC (Experiment 1)

Soluble sugars were measured using GLC according to the method of Holligan and Drew (1971). A known volume of the cleared and deionized extract was dissolved in 0.85 ml of anhydrous pyridine and silylated with 0.1 ml of hexamethyl disilazane and 0.05 ml of trimethyl chlorosilazane, and left over night. A small volume (1–5 ml) of the solution was then injected into a PYE UNICAM series 204 GLC. The temperature of the column was set at 140–290°C at 4°C a minute. The detector and the injector were set at constant temperatures of 350° and 260°C, respectively. Two coiled glass columns (5 feet [152.4 cm] long and 4 mm internal diameter) were used, packed with a support phase chromosorb WHP, 100–200 mesh size (diatom skeletons) coated with a stationary phase, 2% SE 52 silicon gum.

Photosynthesis in the presence of $^{14}CO_2$ (Experiment 2)

Leaf segments were laid on damp filter paper in transparent plastic boxes fitted with two holes to allow the injection of radioactive solution. $NaH^{14}CO_3$ (50 µl), diluted to give 37 kBq/µl or 1 µCi/µl, was placed in the central dish. To release $^{14}CO_2$, 1 ml of 10% lactic acid was injected into the central dish. The box was left under fluorescent light for 30 min., after which 1 ml of 10% NaOH was injected into the second dish to absorb residual $^{14}CO_2$.

Eight feeding boxes were used, containing a total of 32 samples representing 2 cultivars × 2 treatments × 2 harvests × 4 replicates.

Carbohydrates were extracted with 3 × 5 ml hot 80% ethanol for 15 min.; the volume of extract was then reduced under compressed air to 3–4 ml, cleared by adding a similar volume of aluminum hydroxide, $Al(OH)_3$ (20% w/v in water), and deionized with equal weights of Amberlite, IR-45 (OH^-) and IR-120 (H^+).

Radioactivity in ethanol-soluble and -insoluble carbohydrates was counted using a scintillation counter (Packard Tri-CARB 300c and 300cd). Scintillation cocktail was prepared as follows: 4 g PPO (2,5 diphenyl oxazole) and 0.1 g POPOP [(5 phenyl oxazolyl)-benzene] were dissolved in 1 L of a mixture of toluene and triton X-100 (2/1 v/v). Samples (100 ml) were placed in scintillation vials with 10 ml of scintillation cocktail. The counting time for all the samples was 10 minutes.

Results and Discussion

In the first experiment, water stress resulted in a significant increase in soluble sugars (fructose, glucose, inositol and sucrose) in leaves of MBB (Fig. 1a), while only inositol and fructose increased significantly in Capdur (Fig. 1b). The glucose content was much higher than either fructose or surcose in leaves of stressed plants of MBB.

In the second experiment, both immediately after photosynthesis in $^{14}CO_2$ and following a 3-h chase period, the carbohydrate fraction showed an increased incorporation of ^{14}C into ethanol-soluble carbohydrate (ESC) fraction in stressed leaves, compared with controls (Fig. 2). In both cultivars the radioactivity of the sugar fraction rose during the chase period. The incorporation of ^{14}C into the ethanol-insoluble carbohydrate (EIC) fraction, however, was greatly reduced by water stress in both cultivars in both the pulse and chase periods (Fig. 3). A higher turnover in the soluble fraction is indicated by the increase in ^{14}C within 3 h of feeding, particularly in stressed plants (Fig. 2), whereas the insoluble fraction remained relatively stable (Fig. 3).

The responses to water stress of the two cultivars of wheat, MBB and Capdur, indicated the ability of these plants to increase the level of the major sugars found in wheat (sucrose, glucose, fructose), as well as a slight increase in inositol, a cyclitol found in smaller amounts. MBB, which is more tolerant of water stress, showed higher and more significant increases in sugars, especially glucose, than the less-tolerant Capdur.

Increased concentrations of soluble sugars occur under water stress in various species (Eaton and Ergle 1948). High level of sugars was correlated with dehydration-tolerant species such as xerophytes (Iljin 1957) and the so-called 'resurrection plants' (Gaff 1980), which are known to tolerate even complete dehydration without injury. Mesophytes are usually sensitive to dehydration compared with xerophytes and even small water losses may have drastic effects. Different abilities of mesophyte species, or even varieties of crop plants such as wheat, to accumulate sugars under conditions of water stress may indicate different abilities to withstand dehydration.

The radioactive-labelling experiment (experiment 2) was designed to investigate the relative incorporation of recently fixed $^{14}CO_2$ into ethanol-soluble and -insoluble

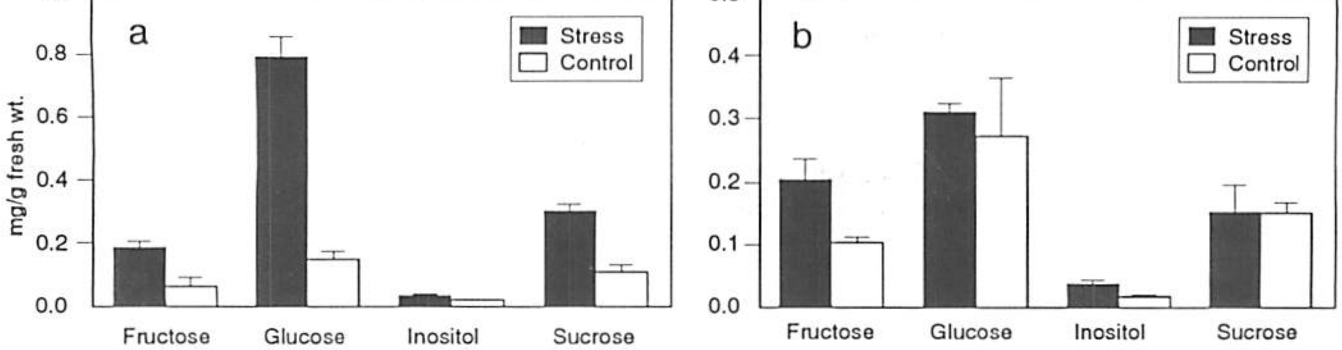

Figure 1. Effect of water stress on ethanol-soluble carbohydrates in wheat of MBB (a) and Capdur (b). Means of 4 replicates; bars indicate standard errors.

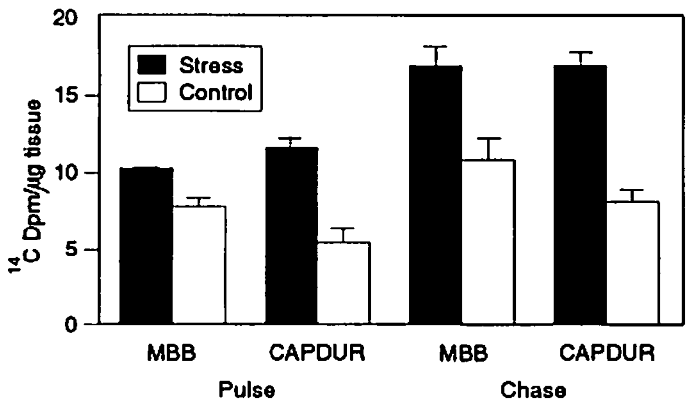

Fig. 2. Amount of ^{14}C incorporated into ethanol-soluble carbohydrates after a pulse and a 3-h chase period.

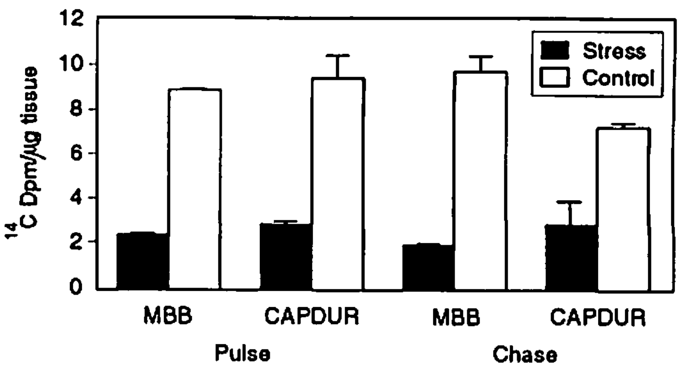

Fig. 3. Amount of ^{14}C incorporated into ethanol-insoluble carbohydrates after a pulse and a 3-h chase period.

carbohydrate (ESC, EIC) fractions. The higher incorporation of ^{14}C into ESC compared with the EIC fraction under water stress observed in both cultivars may reflect a shift in the flow of carbon towards producing low molecular weight and osmotically active compounds such as soluble sugars. Less synthesis of osmotically inactive large molecules, such as starch, under water stress may be indicated by the relatively low level of ^{14}C in the EIC fraction.

This conclusion is supported by the results of Husic and Tolbert (1986) on the green alga *Chlamydomonas* subjected to osmotic stress, where the alteration in carbon metabolism resulted in glycerol accumulation. The suggestion that hydrolysis of previously stored starch may contribute to the increase in soluble sugars has been put forward, but is not covered here.

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Effects of Grass Clippings on Forage and Grain Yield of the Greek Triticale Cultivar Niovi

تأثير حش الأعشاب على الغلة العلفية والحبية لصنف التريتيكال اليوناني نيوفي

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Abstract

The objective of this study was to determine the effect of a number of grass clippings on both the total dry forage and the final grain yield of the Greek Triticale (×*Triticosecale* Wittm. ex A.Camus) cultivar Niovi. The experiments were carried out at the Animal Research Institute of Giannitsa during the growing seasons 1986/87 and 1987/88, at the Cereal Institute of Thessaloniki and at the Horticultural Station of Neapolis Kozanis during the growing season 1986/87. The following five treatments were applied: (a) no clipping (K0), (b) one winter clipping (K1), (c) two clippings, the first at a plant height of 20 cm (winter) and the second one at 25 cm (spring) (K2a), (d) two clippings, both at a plant height 25 cm (spring) (K2b), and (e) three clippings at plant heights 15 cm (winter), 20 and 25 cm (spring), respectively (K3). Treatment K2b produced the most forage at all locations and years but the lowest grain yield of all treatments, except for K3. Among all clipping treatments, K1 gave the highest grain yield, but produced the least forage in almost all cases.

الملخص

كان الهدف من هذه الدراسة تحديد تأثير عدد من حشات الأعشاب على كل من مجمل الغلة العلفية الجافة والغلة الحبية النهائية لصنف التريتيكال اليوناني (x *Triticosecale* Wittm. ex A. Camus) نيوفي. ونفذت التجارب في معهد جيانيستا لبحوث الحيوان خلال موسمي الزراعة 87/1986 و88/1987، وفي معهد سالونيك للحبوب وفي محطة نيبوليس كوزانيس للبستنة خلال الموسم الزراعي 87/1986. وقد استخدمت المعاملات الخمس التالية : (أ) بدون حش (K0)، (ب) حشة شتوية واحدة، (جـ) حشتان، الأولى عندما كان طول النبات 20 سم (في الشتاء)، والثانية عندما كان طول النبات 25 سم (في الربيع) (K2a)، (د) حشتان، وكلاهما عندما كان طول النبات 25 سم (في الربيع) (K2b)، و(هـ) ثلاث حشات عندما كان طول النبات 15 سم (في الشتاء)، 20 سم و25 سم (في الربيع)، على التوالي (K3). لقد أعطت المعاملة K2b أعلى غلة علفية في جميع المواقع والسنوات، إلا أنها أعطت أدنى غلة حبية بين جميع المعاملات باستثناء K3. ومن بين جميع معاملات الحش، أعطت K1 أعلى غلة حبية، إلا أنها أعطت أقل غلة علفية في معظم الحالات تقريباً.

Key words: triticale; grain; yields; grasses; feed crops; pruning.

Introduction

In Greece, an area of about 50,000 hectares is planted to several species for grazing each year. Among the planted fields many are unfertile and/or saline or acidic. The dominant planted species are small-grain cereals, especially barley and oat (National Statistics Service of Greece 1986). The preference for barley and oat lies in their ability to give good forage and hay yield under such soil conditions.

Since the early 1980s, triticale has been cultivated in Greece for grain only, while in other countries (e.g. Mexico and England) it is grazed during early growth stages and then left for grain production (Gregory 1975). Although the nutritional quality of triticale seeds is similar, and in some cases superior, to wheat (Varunghese et al. 1987), information about its use as a forage crop is limited. When triticales are used as forage crops, they exhibit higher forage potential and protein content than oat, and higher forage and silage yields than wheat, rye, oat and barley (Varunghese et al. 1987). Clipping triticales once at the end of tillering gave dry forage yield from 1.97 to 5.58 t/ha and decreased grain yield by between 9.6 and 50.8% compared with the unclipped check (Nachit 1983). More information exists on wheat and rye from grazing and clipping experiments. For soft wheat, one clipping under favorable climatic conditions did not affect the grain yield significantly. However, more than one clipping decreased the yield significantly (Skorda 1973). In early sown and irrigated wheat, grazing by February did not affect grain yield significantly (Winter and Thompson 1987), but grazing up to mid-March when the plants were 15 cm tall increased yield (Sharrow and Motazedian 1987). In semidwarf wheat varieties the taking away of grass from early growing stages to the end of tillering significantly decreased grain yield (Pumphray 1970). For rye, continued clipping of grass had a negative effect on plant growth and decreased forage yield (Holt 1962).

The objective of the present study was to determine the effect of a number of clippings on the total dry forage and the final grain yield of the Greek triticale cultivar Niovi.

Material and Methods

Field experiments were conducted during the growing season 1986/87 at three locations (Animal Research Institute at Giannitsa, Cereal Institute of Thessaloniki and Horticultural Station of Neapolis Kozanis). The same experiment was repeated during 1987/88 at Giannitsa. The experimental design was a randomized complete block with four replications and five treatments applied on the Greek hexaploid triticale cultivar Niovi, which was selected at the Cereal Institute of Thessaloniki from segregating material from the International Maize and Wheat Improvement Center (CIMMYT). This is one of the most productive triticale cultivars in Greece (Ministry of Agriculture of Greece and National Agricultural Research Foundation – Cereal Institute of Thessaloniki 1991). The field plots consisted of seven rows 7.7 m long and 0.26 m apart, and were sown on 28 November 1986 and 21 December 1987 at the rate of 250 kg seed/ha. Each experiment was fertilized with 200 kg N/ha and 50 kg P_2O_5/ha at sowing, and 50 kg N/ha after each clipping. From each plot, the five inner rows were harvested. Clippings were performed using small sickles at 5–6 cm above ground level. There were five treatments: (a) no clippings (K0), check; (b) one clipping when plant height reached 25 cm (K1); (c) two clippings, the first at the end of winter when the plants were 20 cm tall, and the second at the beginning of spring, when plants were 25 cm tall (K2a); (d) two clippings, at the beginning and in the middle of spring, both when plants were 25 cm tall (K2b); and (e) three clippings, at the end of winter, at the beginning of spring and in the middle of spring, when the plants were 15, 20 and 25 cm tall, respectively (K3). All clippings were done before plants finished tillering. Harvested material was weighed immediately. Samples (1 kg) were taken from each plot and dried in an electric oven at 70°C for 18 hours. The dried samples were weighed and the grass production in each plot was estimated on the basis of the dried samples.

At the end of the growing season, the grain yield for all treatments was measured and corrected for moisture content.

Results and Discussion

Significant differences were found for grain yield as well as dry forage production among treatments (clippings) and their interactions with locations and years (Table 1). One clipping (K1) gave the least dry forage of all treatments at Neapolis Kozanis, but gave similar or greater dry forage than two clippings (K2a) at Giannitsa; it also gave significantly more grain yield at all locations and years than all other treatments except for the check. These results confirm the grain yield decrease reported by Nachit (1983), but is contrary to results on soft wheat (Skorda 1973) where grain yield was not significantly affected by one clipping. This difference of response to one clipping could be partially attributed to the later sowing date of our experiments. However, the grain yield decreases due to K1 were less than those caused by the other treatments (Table 1).

The two late clippings (K2b) gave the highest dry forage of all treatments at Thessaloniki and Giannitsa, and the same dry forage as K3 at Neapolis Kozanis, but decreased the grain yield by the same amount as the K3 treatment at all locations except Giannitsa. Generally, grain yield decreased as the number of clippings increased or as clipping was delayed. Similar observations were made by Pumphray (1970) on wheat grazed by sheep throughout the tillering period.

The effect of clipping on grain yield in the two seasons at Giannitsa was significantly different. The decrease in grain yield due to clipping became more pronounced as the number of clippings increased from one to three. The lower grain yield in 1987/88 could be partially attributed to lower temperatures (Table 2) and rainfall (Fig. 1), particularly the winter drought, which delayed seed germination in the second season.

Table 1. Mean forage and grain yield (kg/ha) of clipped triticale (cv Niovi) at three sites in Greece, 1986/87–1987/88.†

Clipping‡	Giannitsa				Thessaloniki		Neapolis Kozanis	
	1987/88		1987/88		1986/87		1987/88	
	Dry forage	Grain yield	Dry forage	Grain yield	Dry forage	Grain yield	Dry forage	Grain yield
K0 (Check)	–	4415 a	–	3762 a	–	4310 a	–	1330 a
K1	443 c	3297 b	475 c	2790 b	468 d	3125 b	237 c	827 b
K2a	382 d	2660 c	510 c	2435 c	514 c	2347 c	268 b	720 c
K2b	852 a	1982 d	1150 a	1002 d	1180 a	885 d	484 a	452 d
K3	747 b	1492 e	966 b	657 e	982 b	895 d	464 a	380 d
CV (%)	3.6	3.7	3.6	3.0	3.3	3.9	4.0	8.2
LSD $_{0.05}$	35.3	156.4	44.5	100.5	41.0	140.1	23.0	93.9

† Values within the same column followed by the same letter are not significantly different at $P = 0.05$ (Duncan's new multiple range test).

‡ K0 = no clipping; K1 = one clipping when plants reached 25 cm (early spring); K2a = two clippings when plants reached 20 cm and 25 cm (late winter and early spring, respectively); K2b = two clippings when plants reached 25 cm (early and mid spring); K3 = three clippings when plants reached 15, 20 and 25 cm (late winter, early spring and mid-spring, respectively). In each case clipping was 5–6 cm above ground level.

Table 2. Mean monthly temperatures (°C)† in the Giannitsa region.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975–84 (mean)	2.0	2.6	5.7	8.4	13.8	18.6	20.2	18.7	14.7	11.5	6.4	3.3
1986	–	–	–	–	–	–	–	–	–	11.7	6.4	4.2
1987	–1.4	2.6	1.2	8.7	13.8	18.7	20.4	19.4	17.4	10.4	6.8	3.1
1988	2.9	1.8	3.7	9.2	16.2	19.3	20.8	19.3	17.4	–	–	–

† Readings were taken daily at 08:00.

Conclusions

Clipping Noivi triticale for hay twice in the spring (early and mid-season) (K2b) gave the highest dry forage yield while maintaining satisfactory grain yield. A single hay harvest in early spring (K1) gave highest grain yield, but least forage. These two crop-management options should be considered in the light of farm needs and economics. When hay is needed or expensive, the two-clipping option is best, but if hay is cheap or alternative feed is available, one clipping for maximum grain yield is a better option.

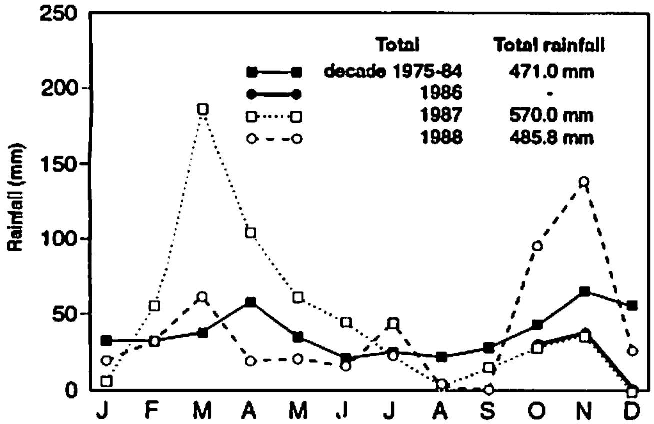

Fig. 1. Rainfall in the Giannitsa region during the period Oct 1986 to Dec 1988.

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Short Communications

Irregular Development of Fertile Lateral Florets in Two-row Barley

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Two-rowed barley (*Hordeum vulgare* L. subsp. *vulgare*) is considered better for malting and brewing purposes than six-rowed barley. Breeding barley for the development of genotypes with long, plump and bold seed has been biased toward improved varieties with good yield coupled with earliness, and disease and pest resistance.

In general, two-rowed barleys have sterile lateral florets, but segregating generations (F_2) of crosses of 6-rowed and 2-rowed types have shown irregular development of fertile lateral florets as a new morphological trait, at various frequencies, and with various shapes and sizes.

Crosses were made between 6-rowed and 2-rowed barleys during *rabi* (winter) 1990/91. Harvested F_1 seeds were all 2-rowed type. The following year, these F_1s were grown in three 5-m rows with a row spacing of 30 cm. Plant-to-plant distance was 25 cm.

A new trait appeared at grain-formation stage, characterized by the present of a fertile lateral floret towards the central axis, with irregular development. In some cases, spikes were longer than normal for 2-rowed barley. This character did not occur in the same variety of 2-rowed barley sown in the same season, in the same plot. All the plants in each cross were closely examined for the character. A higher frequency of abnormal segregants were of 2-rowed type than of 6-rowed (Table 1). This indicates a dominant effect of 2-rowed barley over 6-rowed barley for the character studied.

The percentage of fertile lateral florets was calculated as follows:

$$\text{Fert. lat. fl. (\%)} = \frac{\text{No. 2-row types with fert. lat. fl.}}{\text{Total no. 2-row types}} * 100$$

The frequency of plants exhibiting fertile lateral florets in all crosses (including reciprocals) ranged from 2.56 to 15.38%. Maximum fertile lateral florets were observed in cross 2-rowed barley × NDB 221 and 2-rowed barley × NDB 208 with scores of 15.38 and 11.90%, respectively.

Further genetic studies are being carried out to determine the mode of inheritance for the trait.

Table 1. Frequency of segregants showing fertile lateral florets in the F_2 generation of 2-rowed × 6-rowed barley crosses.

Cross	Total F_2 pop.	2-row sterile lat. fl.	2-row fertile lat. fl.	Freq. fertile lat. fl. (%)
(NDB × 2-row)				
NDB 201	42	33	3	7.14
NDB 207	46	31	4	8.69
NDB 208	39	36	1	2.56
NDB 217	45	39	2	4.44
NDB 221	41	37	4	9.75
NDB 229	36	30	2	5.55
NDB 232	38	33	1	2.63
Reciprocal (2-row × NDB)				
NDB 201	39	36	1	2.56
NDB 207	47	39	2	4.25
NDB 208	42	27	5	11.90
NDB 217	45	39	2	4.44
NDB 221	41	21	6	15.38
NDB 229	36	30	1	2.77
NDB 232	33	27	2	6.06

Fig. 1. Lateral florets in 2-rowed barley: normal (left) and fertile (right).

Elite Lines of Barley Tolerant to Saline–Alkaline Soil

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By virtue of its hardy nature, satisfactory yield, nutritive value and medicinal importance, barley (*Hordeum vulgare* L. subsp. *vulgare*) is an important crop worldwide. Under abiotic-stress conditions (problematic soils), barley thrives and gives better grain yield than other crops. Its high photosynthetic activity and good root development reduce the effect of salinity and alkalintiy in the field. Barley is usually chosen as the first crop in partially reclaimed soils, mainly because of its salt tolerance. Although salt tolerance has been widely reported in many crops (Gupta 1979; Sharma et al. 1987), there is still a need to collect information on tolerance, particularly under field conditions. An experiment was, therefore, planned to study the tolerance of barley to salt and to evaluate barley yield under salinity and alkalinity.

Material and Methods

Twenty-four elite lines of barley plus one standard (Bilara-2), received from different Barley Research Centres—namely Durgapura (Rajasthan), N.D. University of Agriculture and Technology (Faizabad), P.A.U. (Hissar), IARI (New Delhi and Karnal)—were evaluated at two locations (CSSRI, Karnal and the Genetics and Plant Breeding Research Farm of N.D. University of Agriculture and Technology, Faizabad) during *rabi* (winter) 1989/90. Planting was in the last week of November in randomized block design, with three replications. Each plot consisted of six rows, 5 m long, with row-to-row and within-row distances of 23 cm and 10 cm, respectively. Ten competitive plants were taken at random from the middle rows of the plots for recording various observations. Grain yield was recorded on plot basis eliminating border rows. At the time of raising the crop, the soil properties were as follows:

	CSSRI, Karnal	**Kumarganj, Faizabad**
Soil type	Saline–alkaline clay loam	Saline sodic silt loam
pH	8–9	8.9–9.5
ECe (mhos/cm)	3.2–4.20	4.2–4.6

Results and Discussion

A tolerant variety is defined as one with an ability to grow or reproduce itself or to repair injury to a marked degree despite having incurred damage. On the basis of average yield performance, 11 varieties showed high to average tolerance against salinity–alkalinity stress. Of these, five genotypes—RD 2459, DL 200, DL 157, RD 2182 and NDB 207—were found promising and ranked first to fifth, respectively (Table 1). Grain yield ranged from 0.864 to 2.441 tonnes/ha.

Several hulled barleys showed greater tolerance than hull-less types (Table 1). Low yield in a few strains may have been due to genotypic variation as well as to salt effect. Sodic soil adversely affected plant growth and development perhaps due to gross nutritional imbalance; it also severely restricted root systems owing to the poor physical condition and high alkalinity of the soil.

Genotype RD 2459 was the highest yielder (2.441 t/ha) under saline and alkaline conditions, followed by DL 200 (2.255 t/ha), DL 157 (2.225 t/ha), RD 2182 (2.068 t/ha) and NDB 207 (1.955 t/ha). NDB 207, a short-statured genotype, matured relatively early. In the average-tolerance group, promising genotypes were NDB 226, K406, Ratna and Karan 1045, which were agronomically superior and performed well under this abiotic stress.

Considering the various morphological traits and grain-yield potential, the above-cited genotypes may be used as donors for salt tolerance in breeding programs. These elite lines performed better than others in partially reclaimed soil that had saline–alkaline properties.

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Table 1. Summary of morphological traits and grain yield in barley lines grown on saline–alkaline soil, India, 1989/90.

Variety	Days to maturity	Tillering (per m)	Grain yield (t/ha)			
			CSSRI (Karnal)	Faizabad	Average	Rank
RD 2182	111	23	2.824	1.312	2.068	4
RD 2259	106	27	3.165	0.450	1.808	
RD 2407	101	37	2.951	0.845	1.898	
RD 2459	99	26	4.125	0.756	2.441	1
NDB 207	99	33	2.990	0.920	1.955	5
NDB 208	99	26	2.877	0.619	1.748	
NDB 209	95	26	2.615	0.845	1.730	
NDB 217	95	27	2.243	0.724	1.484	
NDB 226	98	26	3.030	0.861	1.945	
K-406	100	29	2.321	0.958	1.890	
K-257	96	24	2.491	0.716	1.605	
K-318	98	18	2.779	0.475	1.627	
K-341	94	23	1.333	0.395	0.864	
BH 278	98	33	2.312	0.829	1.571	
BH 279	98	31	1.961	0.346	1.156	
BH 280	98	35	2.405	0.700	1.535	
Ratna	80	26	3.062	0.688	1.875	
DL-3	100	33	2.998	0.556	1.777	
DL-157	96	32	3.605	0.845	2.225	3
DL 200	94	26	3.922	0.588	2.255	2
Karan 163 (HLS)	94	24	2.339	0.201	1.270	
Karan 521 (HLS)	96	31	2.705	0.636	1.671	
Karan 1041 (HLS)	98	25	2.985	0.354	1.671	
Karan 1045 (HLS)	95	24	2.869	0.700	1.790	
Bilara-2 (Check)	98	46	2.423	0.966	1.025	
		Site Mean	2.794	0.207		
		SEM	0.267	0.024		
		$LSD_{0.05}$	7.56	0.065		
		CV	16.57	20.17		

HLS = hull-less.

Leptosphaeria avenaria on *Hordeum* in Hungary

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Septoria avenae Frank f.sp. *triticea* T.Johnson is a widely distributed pathogen of barley (*Hordeum vulgare* L. subsp. *vulgare*), wheat (*Triticum* spp.) and some other cereals and grasses (Makela 1977; Nyvall 1979; Wiese 1977). It has been recorded in Hungary under the name of *S. passerinii* Saccardo (Bánhegyi et al. 1985); but its perfect state was not mentioned. No severe disease has been observed and attributed to this fungus, and in our screening it was found neither on barley nor on wheat. However, the fungus has been observed sporadically on barley and also causing leaf spot on *Hordeum murinum* L. growing as a weed near a barley field.

The fungus caused similar symptoms on *H. murinum* to those recorded by Nyvall (1979). The pycnidia developed rather diffusely with spots occurring on leaf blades; the morphology of the fungus was similar to that described by Makela (1977), although the conidia were broader than those mentioned by Bánhegyi et al. (1985). Pycnidia were also observed on straw of *H. murinum* and barley.

The perfect state of the fungus (*Leptosphaeria avenaria* Weber f.sp. *triticea* T.Johnson) was not observed on growing barley, but was found on straw. Perithecia of the perfect state were recorded after September, following harvest. Perithecia with eight-spored asci were also observed on *H. murinum* at the base of leaf blades. The ascospores were four celled and constricted at septa (Fig. 1). The spores first appeared hyaline, then became yellowish; their dimensions were 3.6–5.4 × 18.2–24 µm.

The perfect state and the formae specialis of *Septoria avenae* were described from wheat (Johnson 1947). The *Septoria* state could infect barley and was reported as generally distributed on this host (Nyvall 1979). Makela (1972, 1977) also found the fungus on barley, mentioning *H. vulgare* as a common host of *S. avenae* f.sp. *triticea*, but it was considered a weak pathogen. We also observed this fungus with minor importance on *H. vulgare*, but the occurrence of a sexual form on a related weed suggests the possibility of recombination on this host. However, the elucidation of this process, and the opportunity for the appearance of more aggressive forms on *H. murinum* need further investigations.

To the author's best knowledge this is the first report of the ascospore-forming state of this pathogen in Hungary.

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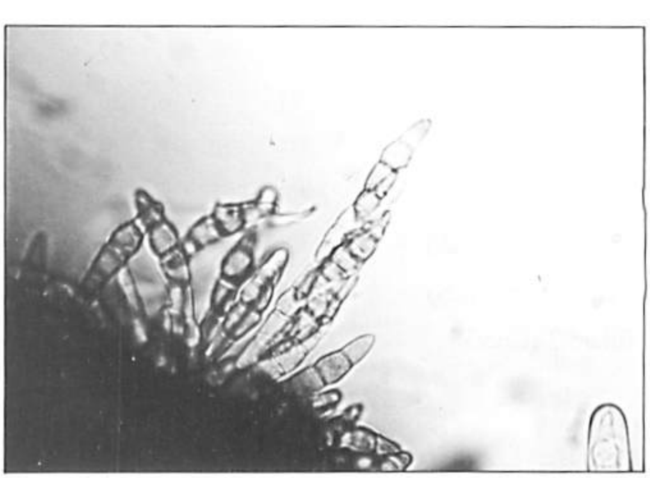

Fig. 1. An ascus with spores of *Leptosphaeria avenaria* f.sp. *triticea*.

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New Bread Wheat Cultivars for Saudi Arabia

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A breeding program for bread wheat (*Triticum aestivum* L. subsp. *aestivum*) was initiated at the College of Agricultural and Food Sciences, King Faisal University, Saudi Arabia, in the late 1970s. Hundreds of local and introduced collections were gathered to form a nucleus for the breeding work. Crosses were made with the following objectives.

1. Breeding high-yielding cultivars that are well adapted to the local conditions.
2. Breeding cultivars that tolerate high salinity and drought conditions.
3. Developing early-maturing cultivars.

KFU 183

KFU 183 was released for Hail and Al-Hassa regions. It was developed at King Faisal University, Al-Hassa, Saudi Arabia.

Origin

KFU 183 is a selection from the cross Probred × Madina (local), made in 1979 at King Faisal University, Saudi Arabia. Twenty-five lines were selected in 1983, and further evaluation reduced the number to four, including lines 183 and 283.

Performance

Over three growing seasons (1985–1987), the mean agronomic characters of KFU 183 were similar to or better than those of the check cultivar Westbred at various locations in Saudi Arabia. However, it flowers and matures earlier, has better straw strength, better lodging and salinity resistance, and heavier grains, but lower tillering capacity (Table 1).

Description

Plants are glabrous throughout; average height 96 cm; nodes darker than internodes; culm straight beneath spike. Spike length 10.5–11.5 cm, medium lax; lower glum asymmetrically keeled, 7.5–9.0 cm long, acuminate with scarious margins, and green veins; upper glum keeled, glabrous with terminal awn 7.5–8.5 cm long. Grain 6–7 mm long, 2.5–3.3 mm broad, uniformly brown and with a compact distal tuft of short yellow hairs.

KFU 283

KFU 283 has high drought and salinity tolerance. It has bread-making qualities suitable for Saudi Arabia. KFU 283 was developed by the plant breeding program of King Faisal University, Al-Hassa, Saudi Arabia. It was tested extensively at various research stations in the country from 1985 to 1987.

Origin

KFU 283 is a selection from the cross Probred × Madina (local) made by the Department of Crops and Forage. Selection was made during the F_2 on a single-plant basis.

Performance

During three years (1985–1987), KFU 283 gave competitive performance compared with the check cultivar Yecora Rojo (Table 2). It also had better yield and tolerance to drought and salinity.

Description

Plants glabrous throughout, average height 81 cm; nodes darker than internodes, culm strongly wavy beneath spike. Spike short-tipped, with green veins and scarious margins; upper glum keeled, glabrous with 3 pale veins on either side of the midvein; awn subterminal and 9.3–9.8 cm long. Grains 7.5–8.3 mm long, 3.5–3.7 mm broad, yellow or (rarely) pale brown, with a compact distal tuft of short yellow hairs.

Seed Multiplication

Seed of KFU 183 and 283 can be obtained from two locations (Hail and Al-Hassa) where they are grown in multiplication fields. These cultivars have been widely accepted by farmers.

Table 1. Yield and agronomic data for KFU 183 and Westbred cultivars from regional variety trials (1985–1987) at various sites in Saudi Arabia.

Location/cv	Yield (t/ha)	1000-grain wt (g)	Plant ht (cm)	Days to flowering	Days to maturity	Flour protein loss (%)	Flour yield (%)
Al-Hassa							
KFU 183	8.4	51.8	95.4	59	104	0.94	70.6
Westbred	8.0	43.8	72.1	69	115	0.32	65.4
KFU Station							
KFU 183	5.6	49.1	89.7	58	99		
Westbred	4.9	44.9	77.9	75	118		
Dairab							
KFU 183	7.0	52.3	92.3	69	110		
Westbred	6.5	40.9	80.0	90	127		
Hail							
KFU 183	5.4	46.9	92.3	72	115		
Westbred	4.2	45.6	70.3	92	130		
Onaiza							
KFU 183	5.6	49.6	96.1	70	118		
Westbred	6.4	43.3	76.3	91	125		

Table 2. Yield and agronomic data for KFU 283 and Yecora Rojo cultivars from regional variety trials (1985–1987) at various sites in Saudi Arabia.

Location/cv	Yield (t/ha)	1000-grain wt (g)	Plant ht (cm)	Days to flowering	Days to maturity	Flour protein loss (%)	Flour yield (%)
Al-Hassa							
KFU 283	7.8	43.8	72.6	64	114	1.25	65.3
Yecora Rojo	6.5	45.8	77.8	72	123	0.85	63.8
KFU Station							
KFU 283	5.8	43.2	82.7	73	120		
Yecora Rojo	5.4	43.7	99.7	82	124		
Dairab							
KFU 283	5.6	45.3	85.3	72	115		
Yecora Rojo	7.0	41.7	71.7	74	121		
Hail							
KFU 283	3.7	42.6	71.3	89	124		
Yecora Rojo	3.8	44.5	65.7	85	123		
Onaiza							
KFU 283	5.3	42.7	69.4	75	125		
Yecora Rojo	5.8	46.0	71.2	73	120		

Response of Wheat to Two Types and Three Methods of Sowing at New Halfa, Eastern Sudan

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Farmers at New Halfa (15°19'N, 38°41'E) grow wheat (*Triticum aestivum* L. subsp. *aestivum*) after pre-sowing irrigation or prewatering mainly to control weeds. They insist on growing wheat after prewatering even if this leads to delayed sowing. They give the prewatering irrigation about 15 days before sowing wheat. Some researchers have found a positive response to prewatering, with a yield advantage of 155 kg/ha (Akasha and Hamdoun 1977).

New Halfa scheme farmers grow wheat mainly on beds 90–120 cm apart. Many researchers have studied different methods of sowing wheat (Khalifa 1966, 1967, 1968; El Rayah 1973) and found differing results.

The objective of this study was to study the response of wheat to growing after prewatering and with different methods of sowing at New Halfa.

Material and Methods

Wheat variety Condor was sown on 1 December 1991. Seeds were broadcast by a wide level disc at the rate of 143 kg/ha. The two types of sowing compared were sowing after prewatering and sowing on dry soil (without prewatering). The three methods of sowing wheat were sowing on flat soil, sowing on 40-cm ridges, and sowing on 120-cm beds. The experimental design used was a split-plot with four replications. Type of sowing was the main-plot factor and method of sowing was the sub-plot factor. The gross plot size was 11 × 46 m, and the net area was 10 × 45 m. The crop was fertilized with urea at the rate of 86 kg N/ha. The crop was irrigated every 14 days and frequent hand-weeding was carried out.

Grain yield, some yield components and some other parameters were studied.

Results and Discussion

Grain yield and seeds/head were significantly different ($P<0.05$) among type-of-sowing treatments. The highest grain yield and number of seeds/head were achieved when wheat was grown after prewatering (Table 1). This result agrees with that of Akasha and Hamdoun (1977).

The type × method of sowing interaction was significant ($P<0.01$) for weight of seeds/head, but not significant for any of the other parameters studied. The highest weight of seeds/head (2.60 g) was obtained under flat sowing after prewatering, while the lowest weight (1.57 g) was produced under 120-cm beds after prewatering.

It seems that prewatering is an important practice which can lead to yield increase if irrigation water is made available early in the growing season, inrespective of sowing method.

Table 1. Wheat grain yield, some yield components and some other parameters under two types of sowing wheat at New Halfa, Sudan.

Sowing type	Grain yield (t/ha)	No. heads/ m^2	No. seeds/ head	Wt seeds/ head (g)	1000-grain wt (g)	Plant stand (m^{-2})†	Plant ht (cm)
Prewatering	3.47	409	36	2.17	38.6	292	79.5
Dry soil	2.81	377	32	2.11	38.8	325	80.0
Mean	3.14	393	34	2.14	38.7	309	79.8
SE ±	0.05	11.1	0.6	0.11	1.53	21.4	3.12

† Plant stand recorded two weeks after sowing.

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Effect of Simulated Rain at Heading Stage on Grain Yield of Wheat

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Farmers often claim that rain at heading stage reduces grain-set of wheat (*Triticum aestivum* L. subsp. *aestivum*). If this is true, the mechanism of reduction in number of grains is not clear. No study appears to have been published regarding this phenomenon.

Wheat flowers are enclosed within the glumes of the spikelet. At the time of fertilization, the lodicules that are located between the ovary and the surrounding glumes, swell. Swelling of lodicules forces the glumes of the spikelet to open; the filaments of the pollen-producing stamens then elongate and extrude from the flower (Stoskopf 1981). It was speculated that falling rain water at the time of glume opening may simply wash out pollen-grains by mechanical action, and that could be the mechanism of grain-set reduction. Guided by this speculation and considering the fact that flowering lasts several days per spike, the treatments for this trial were formulated.

The objective of the present study was to verify the farmers' claim of seed-set reduction due to rain at heading and to clarify the speculated mechanism for the phenomenon.

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Material and Methods

The experiment was conducted at the Regional Agricultural Research Station, Jamalpur, Bangladesh during two growing seasons, 1989/90 and 1990/91. Four treatments were used: T_1, plants exposed to simulated rain for 4 h at the onset of head-emergence; T_2, exposed to simulated rain for 4 h at complete head-emergence; T_3, exposed to simulated rain for 4 h at five days after complete head-emergence; T_4, plants experienced no rain. For the simulation of rain, an artificial shower was used.

Plants were grown in pots and each treatment was replicated three times. Fifteen seeds of the variety Kanchan were sown per pot and seedlings were thinned to 10/pot shortly after emergence. Nitrogen, phosphorus, potassium and sulfur were added at the rate of 100 kg N, 60 kg P_2O_5, 40 kg K_2O and 20 kg S/ha, all applied before seeding. The pots were watered to field capacity daily or more frequently during periods of high water demand.

When the pots with a particular treatment were showered, the remaining pots with other treatments including control were irrigated to maintain equal soil moisture regime in all the pots.

For timing of shower and grain analysis, main mother heads were considered. Data for each treatment were based on 30 plants. Significance between treatment means was established using Student's t test.

Results and Discussion

In the trial of 1989/90, more grains (42) were obtained from the heads which did not experience any rain at heading stage (control). In all other treatments, number of grains/spike was reduced significantly compared with the control. Maximum reduction in number of grains (14.3%) occurred with plants exposed to shower at complete head-emergence or at five days after complete head-emergence. Showering of plants at the onset (very beginning) of head-emergence caused a 9.5% reduction in number of grains.

In 1990/91, a statistically significant reduction in number of grains (42%) was observed in the treatment with the shower at complete head-emergence. Grain reductions in other treatments were not significant ($P>0.05$). However, showering just at head-emergence reduced grain by 10.5%. This value although not significant is similar to that obtained in the previous season (9.5%).

A contrasting result was shown by the treatment with showering at five days after complete head-emergence. This season it reduced grain by only 5.2%, whereas in the previous season it significantly reduced grain by 14.3%. In the second year, the timing of showering probably did not coincide with that of glume opening.

Grains obtained from the treatments with a shower were well-filled, of normal type and similar to those from the control.

Reduction in grain number also caused reduction in grain weight/spike. In 1989/90, grain weight was reduced by up to 16.7% as a result of showering at complete head-emergence and five days after complete head-emergence. In 1990/91, showering at complete head-emergence reduced grain weight by up to 26.7%.

On the basis of the present study, the following conclusions may be drawn: (1) farmers' observation that rain at the heading stages can reduce grain yield of wheat is confirmed—grain weight/spike decreases as a consequence of grain-set reduction; and (2) the speculated mechanism that rain at the time of glume-opening washes out pollen-grains seems responsible for the reduction of number of grains in wheat.

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Table 1. Wheat grain characteristics as influenced by simulated rain at different stages of heading, Jamalpur, Bangladesh.

Treatment	1989/90				1990/91			
	No. grains/spike		Grain weight/spike (g)		No. grains/spike		Grain weight/spike (g)	
	Mean ± SE	Reduction against control (%)	Mean ± SE	Reduction against control (%)	Mean ± SE	Reduction against control (%)	Mean ± SE	Reduction against control (%)
Shower at the onset of head-emergence (T_1)	38 ± 1.4	9.5*	1.6 ± 0.1	11.1	34 ± 2.1	10.5	1.3 ± 0.1	13.3
Shower at complete head-emergence (T_2)	36 ± 1.5	14.3**	1.5 ± 0.1	16.7*	22 ± 2.3	42.0**	1.1 ± 0.1	26.7**
Shower 5 days after complete head-emergence (T_3)	35 ± 1.9	14.3**	1.5 ± 0.1	16.7*	36 ± 2.2	5.2	1.4 ± 0.1	6.7
No shower (control, T_4)	42 ± 1.3	—	1.8 ± 0.1	—	38 ± 1.6	—	1.5 ± 0.1	—

* significant at $P \leq 0.05$; ** significant at $P \leq 0.01$.

Cereal News

Editorial Note

Technical reviewers of *Rachis*

Habib Ketata joined ICARDA in 1983 as Cereal Training Officer, and was recruited to the *Rachis* editorial committee in time to start work on Volume 3 Number 1 (1984). He has served on the editorial committee ever since, and has been the senior technical editor for *Rachis* for many years.

In May 1997, Habib moved to Ankara, Turkey, to take up the position of Winter/Facultative Bread Wheat Breeder for the Turkey/CIMMYT/ICARDA International Winter Wheat Improvement Program (IWWIP). The move is part of a recent CIMMYT/ICARDA agreement on winter/facultative wheat improvement in West Asia and North Africa (WANA).

We wish to take this opportunity to thank Dr Ketata for his many years of service to *Rachis*, and to wish him every success in his new venture.

Observant readers will also notice a change in the senior editorial committee member for *Rachis*. Salvatore Ceccarelli was appointed Acting Leader of the Germplasm Program, and took up the *Rachis* mantle, when Mohan Saxena became first Research Coordinator, and then Assistant Director General, at ICARDA. Many *Rachis* readers will be familiar with Dr Ceccarelli's work on spring barley breeding at ICARDA, since he has many contacts throughout WANA and beyond.

The editorial committee of *Rachis* would like to take this opportunity to thank the scientists from various research programs at ICARDA who have helped in bringing this issue to press.

Forthcoming Events

1998

***13th Iranian Plant Protection Congress*, Shahid Chamran Ahwaz University, Iran, 26–31 March.** Contact: M. Izadayr, Secretary of the 13th Iranian Plant Protection Congress, P.O. Box 1454, Tehran 19395, Iran [Fax +98-21-240-3691 or 240-2570].

***British Mycological Society International Symposium "Future of Fungi in the Control of Pests, Weeds and Diseases,"* Southampton, UK, 6–9 April.** Contact: Dr Tariq M. Butt, IACR-Rothamsted, Harpenden, Herts AL5 2JQ, UK [E-mail *Tariq.Butt@bbsrc.ac.uk*].

***II International Workshop on Control Applications in Post-harvest and Processing Technology*, Budapest, Hungary, 3–5 June.** Contact: Prof. I. Farkas, Department of Physics and Process Control, University of Agricultural Sciences, Gd11, Pater K u 1, 2103 Hungary [Fax +36-2831-0804; e-mail *ifarkas@fft. gau.hu*].

***2nd International Workshop on* Bemisia *and Geminiviral Diseases*, San Juan, Puerto Rico, 7–12 June.** Contact: Mrs D. Guy, Secretary-Treasurer, 2120 Camden Road, Orlando, FL 32803-1419, USA [Tel. +1-407-897-7304; Fax +1-407-897-7337; e-mail *rmayer@ ix.netcom.com*].

***III International Symposium on the Taxonomy and Nomenclature of Cultivated Plants*, Edinburgh, UK, 20–26 July.** Contact: Dr C. Alexander, Royal Botanic Garden, Inverleith Row, Edinburgh EH3 5LR, UK [Fax +44-1315-527171; e-mail *c.alexander@rbge. org.uk*].

***9th IUPAC International Congress of Pesticide Chemistry. "The Food-Environment Challenge,"* London, UK, 2–7 August.** Contact: Dr John F. Gibson, Pesticide Chemistry, The Royal Society of Chemistry, Burlington House, London W1V 0BN, UK [Tel. +44-171-437-8656; Fax +44-171-734-1227; e-mail *iupac98@rsc.org*].

***8th International Symposium on Microbial Ecology*, Halifax, Nova Scotia, Canada, 9–14 August.** Contact: Meeting Planners, Ardenne International Inc., Suite 444, World Trade & Conference Centre, 1800 Argyle Street, Halifax, Nova Scotia, B3J 3N8, Canada [Fax +1-902-423-2143; e-mail *ardenne@fox.nstn.ca*].

***The VIIth International Congress of Plant Pathology*, Edinburgh, UK, 9–16 August.** Contact: Dr J. Royle, Chairman, 7ICPP, Long Ashton Research Station, AFRC Institute of Arable Crop Protection, Long Ashton, Bristol BS18 9AF, UK [Fax +44-1275-394-007; e-mail *david.royle@bbsrc.ac.uk*].

***Downy Mildew Workshop*, at the VIIth ICPP, Edinburgh, UK, 9–16 August.** Contact: Dr Peter T.N. Spencer-Phillips, Department of Biological Sciences, University of the West of England, Coldharbour Lane, Bristol BS16 1QY, UK [Fax +44-117-976-3871; e-mail *p5-spenc@uwe.ac.uk*].

***XV Eucarpia General Congress, "Genetics and Breeding for Crop Quality and Resistance,"* Viterbo, Italy, 21–25 September.** Contact: Dr Mario A. Pagnotta, XV Eucarpia Congress, University of Tuscia, Via S.C. de Lellis, 01100 Viterbo, Italy [Fax +39-761-357256; e-mail *eucarpia@unitus.it*].

***International Symposium on Breeding of Small Grains*, Kragujevac, Yugoslavia, November 1998.** Contact: Breeding of Small Grains Symposium Secretariat, ARI SERBIA, Center for Small Grains, Zeleni venac 2/III, 11000 Beograd, Yugoslavia [Fax +381-11-628-398; e-mail *Breed98@uis0.uis.kg.ac.yu*].

1999

***6th International Conference on* Pseudomonas syringae *pathovars*, Stellenbosch, South Africa, 24–27 March 1999.** Contact: Dr E. Lucienne Mansvelt, Infruitec, Private Bag X5013, Stellenbosch 7599, South Africa [E-mail *lucienne@infruit2. agric.za*].

***XVI International Botanical Congress*, Saint Louis, Missouri, USA, 1–7 August 1999.** Contact: The Secretary General, XVI IBC, c/o Missouri Botanical Garden, P.O. Box 299, St Louis, MO 63166-0299, USA [Fax +1-314-577-9589; e-mail *ibc16@mobot.org*].

Contributors' Style Guide

Rachis publishes the results of recent research on barley and wheat, in English with Arabic abstracts. Articles should be brief, confined to a single subject and be of primary interest to researchers, extension workers, producers, administrators and policy-makers in the field of barley or wheat research. Articles submitted to *Rachis* should not be published or submitted to other journals or newsletters.

The views expressed and the results presented in *Rachis* are those of the author(s) and not the responsibility of ICARDA. Similarly, the use of trade names does not constitute endorsement of or discrimination against any product by ICARDA.

Manuscript

Contributions should be sent to: Rachis/CODIS, ICARDA, P.O. Box 5466, Aleppo, Syria. The name, address, e-mail address (if available), and telex or fax number of the corresponding author should be included in the covering letter. Two good-quality copies of the text should be submitted, typed double-spaced on one side of the paper only. Alternatively, word-processed files in WordPerfect 5 or 6 or Microsoft Word 6 or 7 may be sent as e-mail attachment to: *ICARDA@cgnet.com*, marked "For Rachis newsletter." However, there is a size restriction of 128 kb on incoming e-mail to ICARDA—please discuss in advance if you have any doubts. Figures should be original drawings, good-quality computer print-outs or black-and-white photographs of good quality. Photographs and figures should be suitable for reduction to a printed size of 8.5 or 17.4 cm wide. Photocopies are not acceptable for publication.

All articles must have an abstract (maximum 250 words) and usually the following sections: Introduction, Material and Methods, Results, Discussion, Conclusions and References. Articles will be edited to maintain uniform style, but substantial editing will be referred to the author(s) for approval. Papers requiring extensive revision will be returned to the author(s) for correction. Authors can refer to a recent issue of *Rachis* for format. The following guidelines should be followed.

Include the authority name at the first mention of scientific names.

Present measurements in metric units, e.g. t/ha, kg, g, m, km, ml, L. Where other units are used (e.g. quintal), the metric equivalent should be provided in parentheses.

Define in footnotes or legends any unusual abbreviations or symbols used in the text, tables or figures.

Provide the full name of journals and book titles. Use the following formats for references.

Journal article: Baker, R.J. and K.G. Briggs. 1983. Relationship between plant density and yield in barley. *Crop Science* 23(3): 590–592.

Article in book: Zadoks, J.C. and J.A.G. van Leur. 1983. Durable resistance and host pathogen environment reactions. Pages 125–140 *in* Durable Resistance in Crops. Plenum Publications Corporation, New York, USA.

Article in proceedings: Srivastava, J.P. 1983. Status of seed production in the ICARDA region. Pages 1–16 *in* Seed Production Technology: Proceedings of the Seed Production Technology Training Course – I, 20 April to 6 May 1982, ICARDA/the Government of the Netherlands, ICARDA, Aleppo, Syria.

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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The newsletter of the Lentil Experimental News Service, is produced twice a year at ICARDA in cooperation with the University of Saskatchewan, Canada. Short research articles provide rapid information exchange, and comprehensive reviews are invited regularly on specific areas of lentil research. The newsletter is available free to lentil researchers. An annual supplement to the newsletter contains lentil references, previously issued in *Lentil in AGRIS*. For further information or to subscribe, write to: LENS/CODIS.

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The ICARDA library maintains bibliographic databases for the use of researchers at the center and elsewhere. FABIS and LENS databases contain 6500 and 2800 references, respectively, extracted from AGRIS since 1975 and AGRICOLA since 1970. Literature searches can be conducted by the library staff and results downloaded to diskette or hard copy. Photocopies of up to 5 articles per search can be provided to users, if available. Researchers can request a literature search by letter or telex to: The Manager, LIS.

To obtain further information on these services, please write to the program indicated and state that you saw the advertisement in *Rachis:*

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