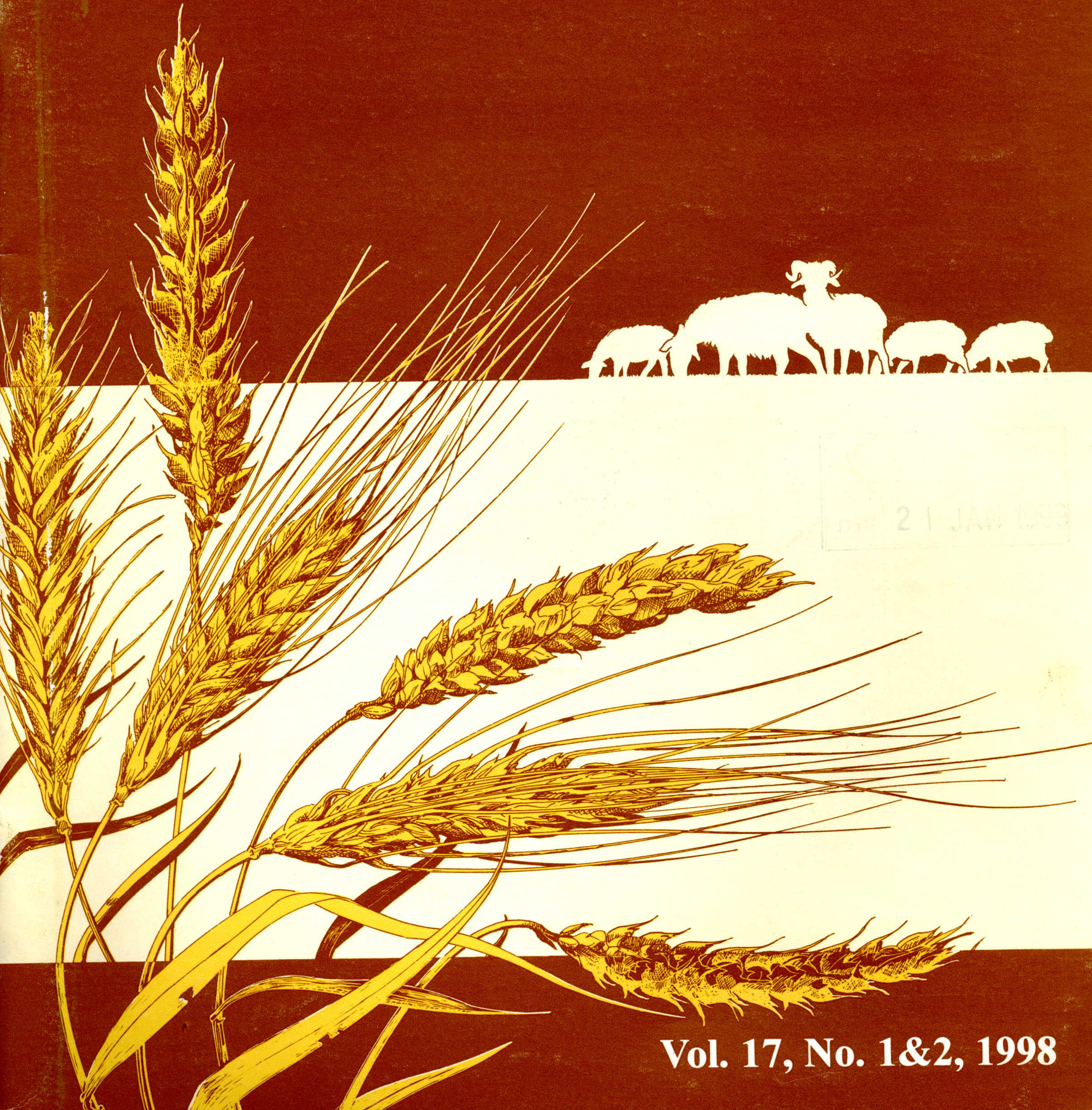
RACHIS

Barley and Wheat Newsletter



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Barley and Wheat Newsletter

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

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Introduction

Since 1994, the International Center for Agricultural Research in the Dry Areas (ICARDA) has adopted specific taxonomic names for its various mandate crops, for use in publishing in international journals and in its crop newsletters (*FABIS Newsletter*, *LENS Newsletter* and *Rachis*). Since that time, many contributors to *Rachis* have seen our preferences and adopted them accordingly. However, the preferred taxa are sufficiently different from those used by some other organizations and in some other publications that we consider it worthwhile to enumerate the names and explain at least some of the choices.

We hope that this paper will provide a useful guide for both contributors to *Rachis* and barley and wheat researchers in general.

Barley, *Hordeum* L.

The taxa of barley follow the treatment of von Bothmer et al. (1991). The principal feature of this classification is that the cultivated crop and its wild progenitor are separated at the subspecific level. Von Bothmer et al. (1991) list over 50 accepted taxa within *Hordeum*; here, however, we restrict enumeration to those which are commonly the subject of agricultural research:

H. vulgare L. subsp. *vulgare*
H. vulgare L. subsp. *spontaneum* (C.Koch) Thell.
H. bulbosum L.
H. murinum L.

In fact these three species comprise the primary genepool of cultivated barley, and form the Section *Hordeum* within the genus. It should be noted that subsp. *vulgare* includes both two-rowed and six-rowed cultivated barley. If the cultivated barleys are separated taxonomically on the basis of number of rows, six-rowed barley becomes *H. vulgare* L. subsp. *vulgare* var. *vulgare*, and two-rowed barley becomes *H. vulgare* L. subsp. *vulgare* var. *distichon* (L.) Alef; however, *Rachis* will not follow this nomenclature. Contrary to the genepool-concept nomenclature followed in *Rachis*, most recent floras separate both the cultivated forms and the wild progenitor at the species level, thus: *H. vulgare* L., *H. distichon* L. and *H. spontaneum* C.Koch (e.g. Meikle 1985).

Wheats, *Triticum* L.

The taxa of *Triticum* (Table 1) follow van Slageren (1994, pages 83–94), who in turn follows MacKey (1966, pages 267–269; 1981, pages 202–203, Table 5) at the species level, with minor alterations. Although only two taxa are commonly cultivated as modern wheats (bread and durum), we provide the full list of accepted taxa, since all are of potential interest in genetic-resources research, in breeding and in 'relic' cultivation. Because of the confusion caused by the multiplicity of names built up over the years, the list also includes basionyms and well-known synonyms.

Wild Wheats or Goatgrasses, *Aegilops* L. and *Amblyopyrum* (Jaub. & Spach) Eig

Taxa for the bulk of the secondary genepool of wheat (Table 2) also follow van Slageren (1994). Van Slageren (1994) gives reasons for keeping the three genera (*Triticum*, *Aegilops* and *Amblyopyrum*) separate, not least of which is the delimitation between the primary (*Triticum*) and secondary (*Aegilops sensu lato*) genepools of wheat. Whereas *Triticum* consists mainly of cultivated taxa and their close wild relatives—the first genepool or GP-1—the *Aegilops–Amblyopyrum* group consists of wild taxa only that are cultivated on a small scale only for research purposes.

Within *Aegilops*, the epithet *ovata* is the subject of much confusion. '*Aegilops ovata*' is currently commonly used for half of Linneaus's original designation—and is referred to as *Ae. ovata* L. *pro parte*. However, confusion has been brought into the use of this name by various attempts to reassign the epithet (*ovata*) to one or other of the two taxa incorporated into Linneaus's original designation. Thus, *Ae. ovata* L. em. Roth also occurs with some frequency in the

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literature. To overcome this confusion, it was necessary to find alternative names for all the taxa represented in Linneaus's original *Ae. ovata* designation. After studying the nomenclature of the names involved, van Slageren (1994, pages 281–283) determined that *Ae. geniculata* Roth is the correct name for *Ae. ovata* L. *pro parte* (to which most references to *Ae. ovata* are to be ascribed), and *Ae. neglecta* Req. ex Bertol. for *Ae. ovata* L. em. Roth. (also well known as *Ae. triaristata* Willd.). In the recent past, several genetic-resources scientists and institutions (ICARDA included) have still been using '*Ae. ovata*' for *Ae. geniculata*.

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Table 1. Accepted taxa within *Triticum* L., as used in *Rachis*.

Accepted taxon†	Ploidy level/ Genome type‡/ Common name	Basionym§	Well-known synonym(s)/Notes
Sect. *Monococcum* Dumort.	Diploid/A		*Crithodium* Link; *Triticum* 'congregatio' *Diploidea* Flaksb.
***T. monococcum* L.**	Diploid/A		
subsp. *monococcum*	Einkorn, or Small spelt wheat		
subsp. *aegilopoides* (Link) Thell.		*Crithodium aegilopoides* Link	*T. aegilopoides* (Link) Balansa ex Körn; *T. baeoticum* Boiss. em. E.Schiem. / Wild taxon
***T. urartu* Tumanian ex Gandilyan**	Diploid/A		Wild taxon
Sect. *Dicoccoidea* Flaksb.	Tetraploid/BA		*Triticum* 'congregatio' *Tetraploidea* Flaksb.
***T. turgidum* L.**	Tetraploid/BA		
subsp. *turgidum*	Rivet, Cone, or Pollard wheat		
subsp. *carthlicum* (Nevski) Á.Löve & D.Löve	Persian, or Persian Black wheat	*T. carthlicum* Nevski	
subsp. *dicoccon* (Schrank) Thell.	Emmer wheat	*T. spelta* [L.] * dicoccon Schrank	*T. dicoccon* (Schrank) Schübl.
subsp. *durum* (Desf.) Husn.	Durum, Macaroni, or Hard wheat	*T. durum* Desf.	

Table 1. ***Continued.***

Accepted taxon†	**Ploidy level/ Genome type‡/ Common name**	**Basionym§**	**Well-known synonym(s)/Notes**
subsp. *paleocolchicum* (Menabde) Á.Löve & D.Löve		*T. paleocolchicum* Menabde	*T. karamyschevii* Nevski
subsp. *polonicum* (L.) Thell.	Polish wheat	*T. polonicum* L.	
subsp. *turanicum* (Jakubz.) Á.Löve & D.Löve	Khorassan wheat	*T. turanicum* Jakubz.	*T. orientale* Percival
subsp. *dicoccoides* (Körn. ex Asch. & Graebn.) Thell.	Wild emmer wheat	*T. sativum* Lam. A *dicoccoides* Körn. ex Asch. & Graebn.	*T. dicoccoides* (Körn. ex Asch. & Graebn.) Schweinf. / Wild taxon
***T. timopheevii* (Zhuk.) Zhuk.**	Tetraploid/GA		
subsp. *timopheevii*			
subsp. *armeniacum* (Jakubz.) Slageren		*T. dicoccoides* (Körn ex Asch. & Graebn.) Schweinf. subsp. *armeniacum* Jakubz.	*T. araraticum* Jakubz. / Wild taxon
Sect. *Triticum*	Hexaploid/BAD		*Triticum* sect. *Spelta* Dumort. *pro parte*; *T.* 'congregatio' *Hexaploidea* Flaksb.
***T. aestivum* L.**	Hexaploid/BAD		*T. aestivum* (L.) Thell. / Alternative correct citation = *T. aestivum* L. em. Fiori & Paol. *pro parte*
subsp. *aestivum*	Bread wheat		
subsp. *compactum* (Host) MacKey	Club, Dwarf, Cluster, or Hedgehog wheat	*T. compactum* Host	
subsp. *macha* (Dekapr. & Menabde) MacKey		*T. macha* Dekapr. & Menabde	
subsp. *spelta* (L.) Thell.	Large spelt, or Dinkel	*T. spelta* L.	
subsp. *sphaerococcum* (Percival) MacKey	Indian dwarf wheat	*T. sphaerococcum* Percival	

† Accepted taxa bold at species level.
‡ Genome formula according to Waines and Barnhart (1992) with tetraploids and hexaploids cited as 'female parent × male parent.'
§ Basionym = first published name for the taxon.

Table 2. Accepted taxa within *Aegilops* and *Amblyopyrum*, as used in *Rachis*.

Accepted taxon†	Ploidy level/ Genome type‡	Basionym§	Well-known synonym(s)¶/Notes
Genus *Aegilops* L.			*Triticum* L. *pro parte*
Sect. *Aegilops*	Diploid/U; Tetraploid/ UC, CU, UM, MU, SU; Hexaploid/UMN		*Aegilops* L. sect. *Surculosa* Zhuk.
***Ae. biuncialis* Vis.**	UM		*Ae. lorentii* Hochst.; *Triticum macrochaetum* (Shuttlew. & A.Huet ex Duval-Jouve) K.Richt.
***Ae. columnaris* Zhuk.**	UM		Not validly combined in *Triticum*
***Ae. geniculata* Roth**	MU		*Ae. ovata* L. *pro parte* / Not validly combined in *Triticum*
***Ae. kotschyi* Boiss.**	SU		*Triticum kotschyi* (Boiss.) Bowden
***Ae. neglecta* Req. ex Bertol.**	UM, UMN		*Ae. triaristata* Willd.; *Ae. recta* (Zhuk.) Chennav.; *Ae. ovata* L. em. Roth; *Triticum neglectum* (Req. ex Bertol.) Greuter
***Ae. peregrina* (Hack. in J.Fraser) Maire & Weiller**		*Triticum peregrinum* Hack. in J.Fraser	*Ae. variabilis* Eig
var. *peregrina*	SU		
var. *brachyathera* (Boiss.) Maire & Weiller	SU	*Ae. triuncialis* L. var. *brachyathera* Boiss.	*Triticum triunciale* (L.) Rasp. var. *brachyatherum* (Boiss.) Maire & Weiller
***Ae. triuncialis* L.**			*Triticum triunciale* (L.) Rasp.
var. *triuncialis*	UC		
var. *persica* (Boiss.) Eig	CU	*Ae. persica* Boiss.	Not validly combined in *Triticum*
***Ae. umbellulata* Zhuk.**	U		*Triticum umbellulatum* (Zhuk.) Bowden
Sect. *Comopyrum* (Jaub. & Spach) Zhuk.	Diploid/M, N	*Aegilops* L. subg. *Comopyrum* Jaub. & Spach	*Comopyrum* (Jaub. & Spach) Á.Löve
***Ae. comosa* Sm. in Sibth. & Sm.**			*Triticum comosum* (Sm. in Sibth. & Sm.) K.Richt.
var. *comosa*	M		
var. *subventricosa* Boiss.	M		*Ae. comosa* subsp. *heldreichii* (Holzm. ex Boiss.) Eig; *Triticum heldreichii* (Holzm. ex Boiss.) K.Richt. forma *subventricosum* (Boiss.) Hayak; not combined at variety level in *Triticum*

Table 2. ***Continued.***

Accepted taxon†	**Ploidy level/ Genome type‡**	**Basionym§**	**Well-known synonym(s)¶/Notes**
***Ae. uniaristata* Vis.**	N		*Triticum uniaristatum* (Vis.) K.Richt.
Sect. *Cylindropyrum* (Jaub. & Spach) Zhuk.	Diploid/C; Tetraploid/DC	*Aegilops* L. subg. *Cylindropyrum* Jaub. & Spach	*Cylindropyrum* (Jaub. & Spach) Á.Löve
***Ae. cylindrica* Host**	DC		*Triticum cylindricum* (Host) Ces., Pass. & Gibelli
***Ae. markgrafii* (Greuter) Hammer**	C		*Ae. caudata* L.††; *Ae. dichasians* (Bowden) Humphries; *Triticum dichasians* Bowden
Sect. *Sitopsis* (Jaub. & Spach) Zhuk.	Diploid/S	*Aegilops* subg. *Sitopsis* Jaub. & Spach	*Sitopsis* (Jaub. & Spach) Á.Löve
***Ae. bicornis* (Forssk.) Jaub. & Spach**		*Triticum bicorne* Forssk.	
var. *bicornis*	S^b		
var. *anathera* Eig	S^b		*Ae. bicornis* (Forssk.) Jaub. & Spach var. *mutica* (Asch.) Eig; *Triticum bicorne* Forssk. subsp. *muticum* Asch.; not combined at variety level in *Triticum*
***Ae. longissima* Schweinf. & Muschl.**	S^l		*Triticum longissimum* (Schweinf. & Muschl.) Bowden
***Ae. searsii* Feldman & Kislev ex Hammer**	S^s		Not validly combined in *Triticum*
***Ae. sharonensis* Eig**	S^l		*Triticum longissimum* (Schweinf. & Muschl.) Bowden subsp. *sharonensis* (Eig) Chennav.; not validly combined at variety level in *Triticum*
***Ae. speltoides* Tausch**			*Ae. aucheri* Boiss.; *Triticum speltoides* (Tausch) Gren. ex K.Richt.
var. *speltoides*	S		
var. *ligustica* (Savign.) Fiori	S	*Agropyrum ligusticum* Savign.	*Triticum ligusticum* (Savign.) Bertol.; not combined at variety level in *Triticum*
Sect. *Vertebrata* Zhuk. em. Kihara	Diploid/D; Tetraploid/DM̲*, DN Hexaploid/DDM̲, DMS, DMU	(No basionym. Emendation of sect. *Vertebrata* Zhuk.)	*Patropyrum* Á.Löve
***Ae. crassa* Boiss.**	DM̲, DDM̲		*Triticum crassum* (Boiss.) Aitch. & Hemsl.
***Ae. juvenalis* (Thell.) Eig**	DMU	*Triticum juvenale* Thell.	
***Ae. tauschii* Coss.**	D		*Ae. squarrosa* auct. non L.; *Triticum aegilops* P.Beauv. ex Roem. & Schult.

Table 2. *Continued.*

Accepted taxon†	Ploidy level/ Genome type‡	Basionym§	Well-known synonym(s)¶/Notes
Ae. vavilovii **(Zhuk.) Chennav.**	DMS	*Ae. crassa* Boiss. subsp. *vavilovii* Zhuk.	*Triticum syriacum* Bowden
Ae. ventricosa **Tausch**	DN		*Triticum ventricosum* (Tausch) Ces., Pass. & Gibelli
Genus *Amblyopyrum* (Jaub. & Spach) Eig	Diploid/T	*Aegilops* subg. *Amblyopyrum* Jaub. & Spach	
Am. muticum **(Boiss.) Eig**		*Ae. mutica* Boiss.	*Ae. tripsacoides* Jaub. & Spach; *Triticum tripsacoides* (Jaub. & Spach) Bowden
var. *muticum*	T		
var. *loliaceum* (Jaub. & Spach) Eig	T	*Ae. loliacea* Jaub. & Spach	*Triticum tripsacoides* (Jaub. & Spach) Bowden forma *loliaceum* (Jaub. & Spach) Bowden; not combined at variety level in *Triticum*

† Accepted taxa bold at genus and species levels.
‡ Genome formula according to Waines and Barnhart (1992) with tetraploids and hexaploids cited as 'female parent × male parent.' Underlining indicates modification from the same genome types present in diploid species.
§ Basionym = first published name for the taxon.
¶ Including correct citation when taxon is considered to belong in *Triticum* where this is not the basionym, although many taxa are not combined at the same level in *Triticum* as they are accepted in *Aegilops*.
†† *Aegilops caudata* has been rejected by the International Committee for Nomenclature in favor of *Ae. markgrafii*.

Characterization of Spring Barley Cultivars by Hordein Seed Storage Protein Analysis

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Abstract

Seed hordein proteins of 20 spring barley (*Hordeum vulgare* L. subsp. *vulgare*) cultivars originating from three Yugoslav breeding centers and introduced from other areas were analyzed by polyacrilamide gel electrophoresis (PAGE). On the basis of band number (N), relative mobility (Rm) and relative intensity (RI) of electrophoregrams obtained, the cultivars could be clearly differentiated. Although several groups of cultivars gave similar hordein patterns, they could be discriminated by some differences in minor components.

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توصيف أصناف من الشعير الربيعي بواسطة تحليل الهوردينات المُدَّخرة في البذور

الملخص

تم تحليل الهوردينات المُدَّخرة في بذور 20 صنفاً من الشعير الربيعي (*Hordeum vulgare* L. subsp. *vulgare*) مستقدمة من ثلاثة مراكز تربية يوغسلافية ومن مناطق أخرى، بواسطة الرحلان الكهربائي في هلام متعدد أكريل الأميد (PAGE). وانطلاقاً من عدد خطوط اللون (N)، الحركية النسبية (Rm) والكثافة النسبية (RI) لأشكال الرحلان الكهربائي التي تم الحصول عليها، أمكن التفريق بوضوح بين الأصناف. وعلى الرغم من أن العديد من مجموعات الأصناف أعطت أنماطاً متشابهة من الهوردينات، إلا أنه يمكن تمييزها عن بعضها البعض بواسطة بعض الفروقات في المكونات الثانوية.

Key words: *Hordeum vulgare*; spring crops; identification; varieties; electrophoresis; proteins; prolamines; seed storage; polymorphism; Yugoslavia.

Introduction

The methods of quantitative and visual identification of barley cultivars (Hadjichristodoulou 1994) are limited because many morphological, physiological and technological characters of different genotypes are not expressed in a given environment. These characters could vary significantly under unpredictable environmental conditions (Gottlieb 1977; Brown 1978). However, precise identification of barley genotypes is an important issue, especially to the malting and brewing industry, to determine cultivar suitability for processing. Some investigations showed that electrophoresis of hordeins in barley grain could be used as an effective and exact method for barley cultivar identification (Shewry et al. 1978; Marchylo and Laberge 1980, 1981; Marchylo 1987).

Hordein composition in different barley cultivars is extremely heterogeneous (Autran and Scriban 1977), which allows precise differentiation of genotypes by their electrophoretic analysis. Generally, barley cultivar hordeins can be divided into four groups: A, B, C and D, on the basis of the molecular weight differences between their amino acid compositions (Shewry and Miflin 1985).

Considering that hordein composition is normally not affected by environmental factors (location, soil type, fertilization level), it is a genetically stable cultivar character. Hordein polymorphism can therefore be used as a reliable marker for identification of different barley cultivars.

In this study, the method of acid polyacrilamide gel electrophoresis (PAGE) of hordeins was used to identify 20 barley cultivars, commonly produced in Yugoslavia. The hordein structures of the cultivars, which are grown in the central region of the Balkan peninsula, are valid in any other agronomic region where these genotypes are in use.

Material and Methods

Twenty spring barley cultivars originating from five different breeding centers in three countries with different environmental conditions were examined (Table 1). Seed hordein proteins of these genotypes were separated by 10% PAGE in the laboratories of the Faculty of Agriculture in Belgrade according to Draper's (1987) procedure, with some modifications.

For preparation of the samples, barley flour (0.05 g) in vials was extracted with 25% 2-chloroethanol containing urea (18%), methyl green (0.05%) and 2-mercaptoethanol (1%). The tubes were allowed to stay overnight at room temperature. After centrifugation (15 min, 5000 rpm), the supernatant was used for the electrophoresis.

The electrophoresis apparatus used was DYY-IV-28 A vertical gel former with 12 gel slots (135 × 100 × 1.5 mm). About 60 ml stock gel buffer (20 ml glacial acetic acid and 1 g glycine made up to one liter with distilled water) was prepared with the addition of the following compounds: acrylamide (10 g), bisacrylamide (0.4 g), urea (6 g), ascorbic acid (0.1 g) and ferrous sulfate (0.005 g). The solution was stirred and adjusted to 1000 ml volume with the stock gel buffer solution.

For hordein separation, 20 µl samples were used. Electrophoresis was carried out at a constant voltage (380 V) for about two hours, at a temperature not exceeding 25°C. Gel slots were then fixed in 10% trichloroacetic acid (TCA) for half an hour, then stained with 0.04% coomasic brilliant blue R_{250} in 10% TCA solution for 24 hours. After washing up with water, photos were taken.

Results and Discussion

Diagrams of the hordein electrophoregrams of the 20 spring barley cultivars are presented in Figs. 1 and 2. Hordein electrophoresis revealed that hordein composition in most of the cultivars was heterogeneous. Hordein proteins were separated into 9 to 20 distinctive bands. Significant differences in hordein composition were in the relative mobility (Rm) region of 0 to 40, where 100 is the distance of the most mobile band.

Table 1. Origin and pedigree of 20 spring barley cultivars.

No.	Cultivar	Origin	Pedigree
1	Kraguj	YU-Kragujevac	Gerda × Ceres
2	Dunavac	YU-Kragujevac	Georgie × Pirouette
3	Dinarac	YU-Kragujevac	Georgie × Kraguj
4	Jastrebac	YU-Kragujevac	Georgie × Pirouette
5	Zenit	YU-Kragujevac	Union × Gerda
6	Galeb	YU-Kragujevac	CGS-44-74 × Kraguj
7	Biser	YU-Kragujevac	Gerda × Ceres
8	Bonus	Czech Republic	(R964 × HE858) × (R94 × Nadja)
9	Kredil	Czech Republic	Nadja × KM119
10	ZA-15	YU-Zajecar	(Union × Ager) × NS-185
11	ZA-14/84	YU-Zajecar	(Union × Ager) × NS-183
12	Pivarac	Croatia-Osijek	(Osk.4.1/1-70 × Korina) × Triumph
13	Lunar	Croatia-Osijeck	Menuet × OSK.4.27/6-76
14	Lazar	YU-Novi Sad	(NS-320 × NS-135) × NS-185-2
15	NS-332	YU-Novi Sad	(NS-291 × FR 33) × NS-298
16	Pek	YU-Novi Sad	(TU 50-77 × Sandans) × NS-294
17	Vihor	YU-Novi Sad	NS-291 × Sandans
18	NS-316	YU-Novi Sad	(Magnific 102 × NS-96) × Union
19	NS-406	YU-Novi Sad	(E India I 127-76 × Spartan) × (NS-250 × NS-29)
20	NS-310	YU-Novi Sad	(NS-96 × Emir) × FR33

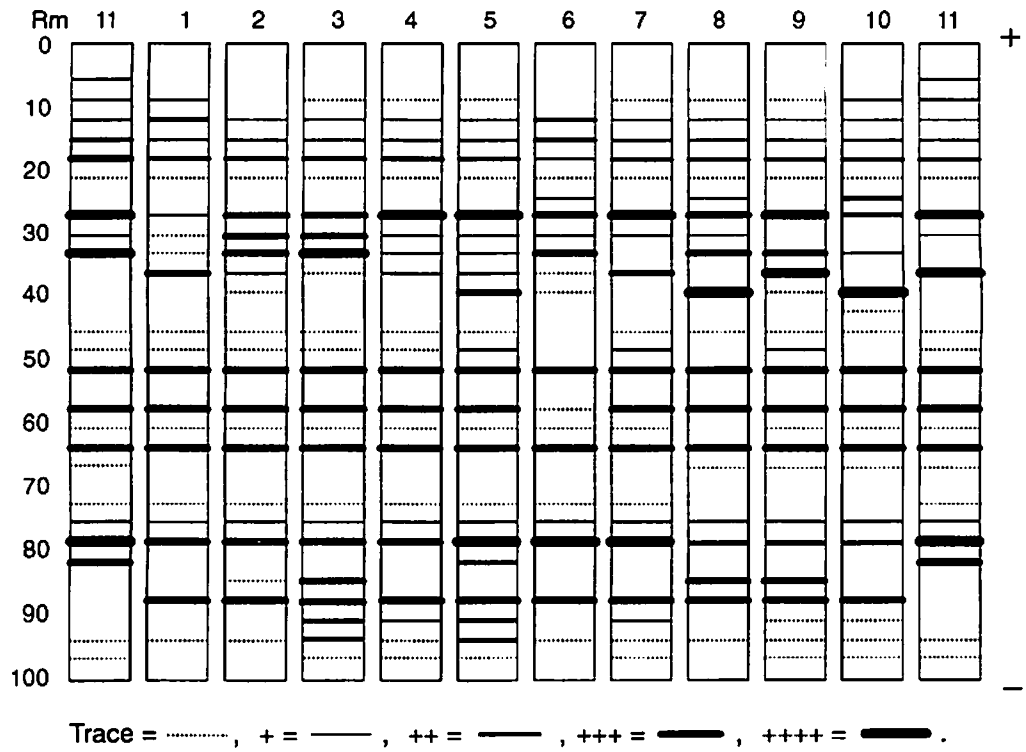

Fig. 1. Diagram of hordein electrophoregrams of spring barley cultivars (1–11): 1. Kraguj, 2. Dunavac, 3. Dinarac, 4. Jastrebac, 5. Zenit, 6. Galeb, 7. Biser, 8. Bonus (KM-341), 9. Kredil (KM-184), 10. ZA-15, 11. ZA-14/84.

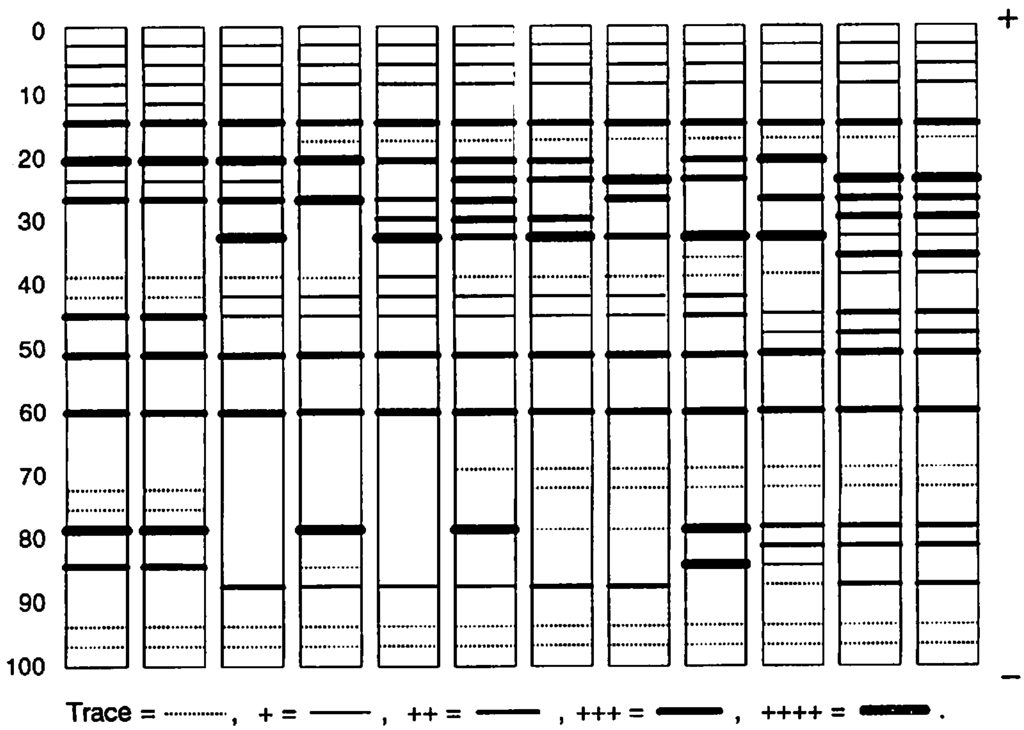

Fig. 2. Diagram of hordein electrophoregrams of spring barley cultivars (11–20): 11. ZA- 14/84, 12. Pivarac, 13. Lunar, 14. Lazar (NS-408), 15. NS-332, 16. Pek (NS-402), 17. Vihor (NS-330), 18. NS-316, 19. NS-406, 20. NS-310.

The hordein electrophoretic pattern of the 20 barley cultivars was examined. Most of the cultivars had distinct patterns, and were characterized by them; 13 were divided into four groups according to their similarity in hordein composition. The first group included five cultivars: Jastrebac, Zenit, Biser, ZA-14/84 and Lunar. The second and third groups included three cultivars each: Dunavac, Dinarac and NS-310, and Kredil, Vihor and NS-406, respectively. The fourth group contained cultivars Lazar and Pek. The remaining seven cultivars were heterogeneous and significantly differed from the above cultivars.

The cultivars could also be characterized according to the presence or absence of some minor components although they seemed to be similar in the most intensive bands within each group. For instance, at Rm 85, Dinarac had a clear band, while the same band was very light for cultivar Dunavac.

The identification of genotypes grown under different environmental conditions can be achieved not only by protein markers, but also by molecular (genetic) markers, such as DNA, using new methods: PCR, TFLP, etc. These new techniques provide genotype identification on the DNA level and their results are compatible with the results of the PAGE method.

Although the material in this study included related cultivars, it appeared that they had special hordein electrophoretic patterns. Therefore, they can be identified by examining their hordein composition. Results showed that it is possible to identify barley cultivars by electrophoretic separation (PAGE method) of hordein proteins.

Conclusion

The analysis of 20 spring barley cultivars grown in Yugoslavia using polyacrilamide gel electrophoresis on the basis of their electrophoregrams showed that hordein composition could be a reliable marker for characterizing diverse barley genotypes. This is especially important because a cultivar grown under different environmental conditions and locations always has the same electrophoretic pattern of hordeins.

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Improvement of Malt Quality of Winter Barley under Dryland Conditions of Central Anatolia

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Abstract

Barley (*Hordeum vulgare* L. subsp. *vulgare*), the second most widely grown cereal in Turkey, is produced mainly for animal feed. Breweries have had to use feed and/or dual-purpose varieties until the late 1980s. Bahri Dagdas International Winter Cereals Research Center started a breeding program specifically for malting barley. The program started with 650 introductions at the research farm in Konya province, which represents Central Anatolia, the largest barley-growing region in Turkey. Observations and tests made in the field, and tests and analyses carried out in the laboratories in different years resulted in the release of a new variety, Karatay 94, suitable for good-quality malt production.

Keywords: *Hordeum vulgare*; winter crops; barley; brewing; quality; arid zones; Turkey.

تحسين جودة ملت الشعير الشتوي تحت الظروف الجافة في وسط الأناضول .

الملخص

ينتج الشعير (*Hordeum vulgare* L. subsp. *vulgare*) الذي يعتبر ثاني محصول من الحبوب التي تزرع على نطاق واسع في تركيا، كعلف للحيوان بشكل رئيسي . وكان على مصانع الجعة أن تستخدم أنواع الشعير العلفية أو الثنائية الغرض أو كليهما حتى أواخر الثمانينات. وقد شرع مركز بحوث بحري داغداس الدولي للحبوب الشتوية في برنامج تربية مخصص لأنواع الشعير التي تدخل في صناعة الجعة . وقد استهل البرنامج عمله بـ 650 مدخلاً في محطة البحوث الواقعة في إقليم قونية ، حيث يمثل الموقع منطقة وسط الأناضول التي تعتبر أكبر منطقة لزراعة الشعير في تركيا. وقد أسفرت المشاهدات والاختبارات التي أُجريت في الحقول، والاختبارات والتحاليل التي نُفذت في المختبرات وعلى مدى سنوات عديدة ، عن اعتماد صنف جديد، كاراتاي 94 ، ملائم لإنتاج ملت جيد النوعية .

Introduction

Central Anatolia is the largest barley-growing region of Turkey. Until the early 1980s, almost 90% of the barley area was cultivated with a winter variety, Tokak 157/37, which was selected from landraces in Central Anatolia for its high adaptation, yield stability, and cold and drought tolerance. Presently, the main purpose of growing barley is for feeding the large animal population in Turkey. However, small amounts of the barley needed by the brewery industry are also being satisfied (Kınacı and Kınacı 1989).

Generally, good malt production can be obtained in mild, cool and rainy weather conditions where the vegetation period is rather long. Under this kind of environment, varieties which are improved for dual purposes and/or for feeding give acceptable or even good brewing quality.

Barley breeding programs carried out for Central Anatolia have been mainly targeted to improve varieties with high-yielding capacity and high protein percentage. These varieties may or may not be appropriate for malt production (Kınacı et al. 1983). In 1985, a private company—Anatolian Brew, Malt and Food Industry—established its malt production factory near Konya, the largest barley-growing province of Turkey. The company also started a research program to improve varieties only for malting purposes. This was the first program specifically targeted to improve such varieties in Central Anatolia, and Efes 3 was the first released variety from this work.

In 1987, a government institution, Bahri Dagdas International Winter Cereal Research Center (BD Mikham), was founded in Konya. The center has independent barley breeding programs for feed and malting barley.

Material and Methods

A research program started in the fall of 1987 in the fields of BD Mikham research farm with 650 introductions obtained from national and international research institutions. The site, which is representative of the region, has low annual precipitation that is not well distributed and varies between 300 and 325 mm, with cold winters and dry, warm summers. Soils of the site are silty loam and clayey loam in texture, with pH of 7.2–8.4, high lime content, poor organic matter ranging from 0.12 to 1.45% and low available Zn content.

Each entry was planted in two rows in 2 m plots, with standard checks planted after every 10 entries. The genotypes were planted at the seed rate of 220 kg/ha and cultural practices were as recommended for good crop production.

Emergence date for each entry was recorded when 50% of the plants in a plot had fully emerged. Cold tolerance was recorded at the end of the winter season according to a 0–9 scale, where 0 = no damage, 1 = trace, 3 = slight, 5 = moderate, 7 = severe, 9 = very severe.

During the growing season, foliar diseases and root rots were observed and scored. Foliar diseases were scored according to a 0–9 scale, where 0 = free from infection, 1–3 = resistant, 4 = moderately resistant, 5 = moderately susceptible, 7 = susceptible and 9 = very susceptible (Anonymous 1981).

Heading date, flowering and ripening were recorded when 50% of the spikes in a plot fully emerged, flowered and ripened, respectively. Lodging, shattering and neck breaking were also observed. Plant height of each genotype was measured from the soil surface to the top of the spikes.

Harvest was done by hand and the harvested bundles were threshed by a Wogel thresher. Grains from each harvested entry were evaluated according to kernel size, shape, aleurone color and 1000-kernel weight.

During the second year (1988/89), the selected lines and/or varieties were planted at three different locations in Konya province in an augmented design. The genotypes which were found to be unsuitable for the region were discarded. Tokak 157/37 and Obruk 86 were used as standard checks for winter hardiness, cold and drought tolerance, shattering and neck breaking; Anadolu 86 and Obruk 86 for lodging; and Tokak 157/37 and Efes 3 for malt quality, test weight and grain hardness.

Malt quality was assessed for the selected entries from the second year evaluation following the standards of the European Brewery Convention (EBC) (Atlı et al. 1989; Çölkesen and Kırtok 1989; Özkara 1989). The entries were also subjected to a germination test—an important physical test for malting. Another physical test applied to the grain was sieving to determine the rate of the first quality or full barley (i.e., the seeds left on a 2.5 and 2.8 mm sieve). The percentage of grain left under a 2.2 mm sieve was taken as the sieve difference. Hardness was visually determined for grains which were cut by a grain cutter (Williams et al. 1988).

During the following year, the selections which were considered more suitable for malt production were subjected to a yield test at three locations in the region. The field plot design was randomized complete blocks with four replications. The plots were 5 × 1.2 m with 6 rows. Standard check varieties were Tokak 157/37 and Anadolu 86. The genotypes were planted at the seed rate of 220 kg/ha. Fertilizer at the rate of 60 kg P_2O_5 and 60 kg N/ha was applied. Cultural practices were as recommended for good crop production at each location.

Results and Discussion

The winter of the 1987/88 growing season was cold and windy. The period of snow cover was short. All genotypes planted in the observation nursery suffered from cold, and many ranked as susceptible or highly susceptible. Drought and diseases under natural infection, particularly loose smut and barley stripe, also affected many entries. Some genotypes lodged and some shattered, but neck breaking was not observed. Genotypes which ripened later than Tokak 157/37 were recorded. Late maturity generally produces more starch grains which are preferable for brewing. Thus, under the harsh conditions of the 1987/88 growing season, 237 genotypes out of 650 were selected.

In the 1988/89 growing season, preliminary yield records of the entries were obtained from the three sites. Genotypes which yielded more than Tokak 157/37 and Obruk 86, and had acceptable levels of winter hardiness and cold, drought and disease tolerance, with good threshing ability, no lodging, shattering or neck breaking were selected and subjected to grain tests. Grain hardness, full barley percent, 1000-kernel weight and germination rate were other selection criteria. For good-quality malt production, full barley should be more than 80% of the total seeds, 1000-kernel weight is preferred to be 36–48 g and germinated seeds should be more than 90% in three days (germination capacity) and 96% in five days (germination ability).

Two promising genotypes, BDMA 23 and BDMA 27 (Table 1), together with the check varieties Tokak 157/37 and Anadolu 86 and 21 other varieties and/or lines, were tested for yield at two locations during the first year (Çumra and Obruk) and at three locations during the second year (Merkez, Çumra and Obruk).

The climate during the second year of the yield trials was unusual for the region. Winter was mild and rainfall was high with good distribution. High yield performance was obtained at Merkez and Obruk locations, which had been normally used as dry-condition test sites. The yield trial conducted at Çumra location, where annual precipitation is around 300 mm, was irrigated.

Compared to the check varieties, BDMA 23 and BDMA 27 gave good yield under Central Anatolian conditions (Table 2). Physical characteristics of the grains (Table 3) and malt properties (Table 4) were also promising for both lines, with a slightly better performance of BDMA 23 in some characteristics. Thus, these two candidates were recommended for registration and were accepted for region-wide state trials that are conducted at 12–14 locations every year. Both lines demonstrated good yield, winter hardiness, and drought and disease tolerance in two successive years. BDMA 23 was accepted by the registration committee mainly for malt production and was released under the name Karatay 94.

Table 1. Values obtained from promising lines (BDMA 23 and BDMA 27) and checks in the first year, 1987/88.

Character	BDMA 23	BDMA 27	Tokak 157/37	Obruk 86	Anadolu 86
Germination capacity (%)	93	100	90	90	91
Germination ability (%)	97	100	95	95	95
Cold tolerance	3	2	3	3	3
Drought tolerance	good	good	good	good	moderate
Barley stripe†	MS	MR	S	MS	MS
Loose smut (%)	9	11	22	18	20
Lodging (%)	0	0	0	5	0
Neck breaking (%)	0	0	0	0	0
Height (cm)	95	95	100	100	100
Shattering (%)	0	0	0	0	0

† R = resistant; M = moderate; S = susceptible.

Table 2. Grain yield (kg/ha) of promising winter barley lines and check varieties at different locations.

	First year		Second year		
Variety/line	Çumra (i)	Obruk	Merkez	Çumra (i)	Obruk
Tokak 157/37 (check)	4890	1930	4830	4340	4670
Anadolu 86 (check)	4310	2340	4770	4000	4700
BDMA 23	6050	1300	4860	6070	3610
BDMA 27	5690	2760	4030	8070	4620

(i) = irrigated.

Table 3. Grain characteristics of two promising lines and two check varieties.

Variety/line	Full barley (%)	Sieve difference (%)	Test weight (kg/hl)	1000-kernel wt (g)
Tokak 157/37 (check)	67.9	9.4	65.5	43
Efes 3 (check)	79.0	3.7	66.0	49
BDMA 23	79.3	3.7	68.0	53
BDMA 27	78.0	5.3	60.0	44

Table 4. Micro-malt analysis results of two promising lines and two check varieties.

	Extract (%)	Difference (%)	Total protein (%)	Kolbach index
Tokak 157/37 (check)	77	2.3	12.2	34.1
Efes 3 (check)	78	2.5	12.2	36.9
BDMA 23	79.5	1.9	12.2	42.5
BDMA 27	77	2.4	12.3	36.2

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Effect of Harvesting Program on Forage and Grain Yields, Digestibility, Nitrogen Concentration, Tillers and Crop Fractions of Spring Barley in Low-Rainfall, Mediterranean Environments

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Abstract

Combinations of three harvesting treatments with three barley *(Hordeum vulgare* L. subsp. *vulgare)* cultivars commercially grown in Cyprus at two sites were compared in a four-year experiment. The harvesting treatments were: a harvest for grain and straw (GS); a milk-stage cut (H), and a grazing-stage cut followed by a milk-stage cut of the re-growth (HC). The barley cultivars used were Morocco-628, Kantara and 48-Alger, grown under rainfed conditions. The milk-stage harvest (H) produced the highest herbage dry matter and *in vitro* digestible yields. The grazing-stage cut (HC) reduced the final hay yield and plant height but increased the total nitrogen yield. At the grazing stage, the proportion of green leaf blade, the concentration of nitrogen and the digestibility (percentage of digestible organic matter in harvested dry matter) of total herbage were relatively high in all three cultivars (means were

تأثير برنامج الحصاد في الغلة العلفية والحبية، قابلية الهضم، تركيز الآزوت، الإشطاءات، وأجزاء محصول الشعير الربيعي في البيئات المتوسطية المتدنية الأمطار

الملخص

تمت في تجربة دامت أربع سنوات ونُفذت في موقعين مقارنة توليفات من ثلاث معاملات حصاد مع ثلاثة أصناف من الشعير (*Hordeum vulgare* L. subsp. *vulgare*) مزروعة في قبرص لأغراض تجارية. وكانت معاملات الحصاد: الحصاد للحصول علي الحب والتبن (GS)، الحصاد في الطور الحليبي (H)، والحصاد في طور الرعي الذي يعقب إعادة النمو بعد الحصاد في الطور الحليبي (HC). وكانت أصناف الشعير المستخدمة في التجربة هي: مغرب – 628 وكنتارا و 48–الجير، وقد زُرِعت تَحت ظروف بعلية. وأعطى الحصاد في الطور الحليبي (H) أعلى مادة جافة علفية وغلة قابلة للهضم في المختبر. كما أعطى الحصاد في طور الرعي (HC) أعلى غلة دريس وطول نبات ولكنه زاد في غلة الآزوت الإجمالية. وفي طور الرعي، كانت نسبة نصل الأوراق الخضراء، تركيز الآزوت وقابلية الهضم (النسبة المئوية للمادة العضوية القابلة للهضم في المادة الجافة المحصودة) لإجمالي المجموع الخضري عالية نسبيا في جميع الأصناف الثلاثة (كانت المتوسطات 77.8، 3.53 و72.9% للصنف مغرب–628، كنتارا، و48–الجير على التوالي). وبوصول النباتات إلى الطور الحليبي، يتناقص عددها في جميع الأصناف (المتوسطات 14، 1.3 و54.0% على التوالي). وكانت قابلية الهضم والآزوت 73.2% و 1.9% في

77.8, 3.53 and 72.9% for Morocco-628, Kantara and 48-Alger, respectively). By the time the plants reached the milk stage, these numbers were reduced in all cultivars (means 14, 1.3 and 54.0%, respectively). Digestibility and nitrogen were 73.2% and 1.9% in grain and 36.8% and 0.6% in straw, respectively. At the grazing-stage cut, the variety Kantara had the highest proportion of stem (26.9%, compared with 20% in the other two varieties), but the lowest proportion at the milk-stage cut (47.3%, compared with 53% in the other two).

الحب و 36.8% و 0.6% في التبن على التوالي. وفي الحصاد في طور الرعي، اتصف الصنف كنتارا بأعلى نسبة من السوق (26.9% مقارنة بـ20% في الصنفين الآخرين) وبأدناها في الحصاد في الطور الحليبي (47.3% مقارنة بـ53% في الصنفين الآخرين).

Key words: *Hordeum vulgare*; feeds; harvesting; grain; yields; digestibility; nitrogen content; tillering; rainfed farming; Mediterranean climate; Cyprus.

Introduction

An earlier paper (Droushiotis 1984) described the effects of harvesting program on yield, digestibility, nitrogen concentration and number of tillers in four barley cultivars. It was considered worthwhile to examine the crop in more detail in order to gain further information and to contribute to a more complete understanding of some other results. In the literature, there is a large amount of information concerning the effect of various factors on barley used either for grain or hay production, but little experimental evidence is available comparing barley harvested at different stages. The two papers (Droushiotis 1984 and the present one) give a more comprehensive set of data on this topic and will assist in a better understanding of the reasons for yield differences in barley and, hence, will enable management decisions to be more soundly based.

Material and Methods

Three barley cultivars, namely, 48-Alger, a six-row barley having a prostrate type of growth suitable for grazing; Kantara, a two-row barley having an erect type of growth suitable for grain yield; and Morocco-628, a six-row barley with an erect type of growth suitable for hay production, were compared for yield and regeneration ability under three harvesting treatments. The treatments were: harvesting once only for grain and straw (GS); harvesting once for hay at the milk stage of grain and again at any worthwhile re-growth (H); and harvesting once at the jointing stage in winter to simulate grazing and again for hay at the milk stage of grain and, finally, at any worthwhile re-growth (HC).

The nine treatments (3 varieties × 3 harvesting treatments) were arranged in a randomized complete design with four replications. The experiment was carried out for four successive cropping years (1988/89–1991/92) at a different experimental site each year in Laxia, and for three years (1988/89, 1989/90 and 1991/92) in Dromolaxia. The experimental sites were fallow in the previous cropping season. Years and sites were combined into seven site–year combinations (environments) and were considered as random effects. The varieties and harvesting treatment combinations were considered fixed effects and were tested using the appropriate error terms, taking into consideration the expected mean squares of the mixed model used, i.e., treatments were tested against the environment × treatment interaction (48 degrees of freedom).

The crops were sown in November with an experimental plot drill in rows, 20 cm apart. The seed rate for treatment GS was 112 kg/ha; for H and HC it was 185 kg/ha. The fertilizer rates were 37 kg P_2O_5 and 30 kg N/ha at sowing, and 30 kg N/ha as top dressing applied to all three treatments after the grazing-stage cut (about mid-January). No potassium was applied. The soils of the experimental fields (loam to clay loam) were representative of the cereal-growing region in Cyprus.

Harvesting started each year in January and was completed in May with the harvest of grain and straw. The herbage was cut with a motor-scythe with a front-mounted cutter bar, leaving a stubble height of about 4–5 cm, and the grain was harvested with an experimental plot combine. The straw was collected in bags fixed on the combine. The fresh weight of the harvested produce of each plot was recorded at harvesting and two samples were taken: one of c. 500 g fresh weight for determination of dry-matter content, digestibility and nitrogen concentration, and the other of c. 150 g for separation into morphological fractions. Total nitrogen was determined by the Kjeldahl method and digestibility by the method of Tilley and Terry (1963) and expressed as the percentage of digestible organic matter in dry matter (D-value).

Grain and straw samples were also collected from all the GS plots for the determination of dry matter, digestible organic matter and nitrogen concentration. Plant height was recorded before each cut as the distance from the soil surface to the top of the plant or the spike (excluding the awns). Barley plants were counted in two half-meter lengths of row in each plot as soon as crop emergence was completed. Surviving barley tillers were also counted in the same lengths of row immediately before each cut. The c. 150 g samples were separated into five components: green leaf, dead leaf, stem, inflorescence of the three sown barley cultivars, and weeds. These morphological fractions were subsequently oven-dried and weighed. Green leaf comprised leaf blades which were more than 50% green, including that part of the youngest leaf which had emerged into the light. Dead leaf comprised leaf blades which were more than 50% yellow or brown. Stem comprised true stem plus leaf sheath plus unemerged leaf and inflorescence. Inflorescence comprised the rachis and spikelets (or that part which had emerged). In the case of plots which were harvested more than once during the course of an experiment, D-values, total nitrogen concentrations and the proportions of different crop fractions over the whole period of the experiment were calculated as means weighted by dry-matter yield. The separation into morphological fractions was done on H and HC and into grain and straw on GS harvesting treatments, but only in two environments. For the total nitrogen and digestibility determination and for the tiller counts, only two blocks from each environment were used.

Results

Rainfall at the experimental sites over the years is presented in Table 1. Rainfall in 1988/89 was about average but the crops suffered from moisture stress during February and March, particularly at Laxia. In 1989/90 and 1990/91, rainfall was well below average, particularly in 1990/91, and the crops suffered from moisture stress during the whole cropping season resulting in very low yields at Dromolaxia and no yields at Laxia. In 1991/92, rainfall in both locations was above average and well distributed over the growing season resulting in very high yields, particularly at Dromolaxia.

On average, treatment H produced 13% more total dry-matter yield than the lowest-yielding treatment HC, while yield of GS was similar to that of H and HC (Table 2). Regardless of whether the harvesting treatments were averaged or examined individually, there were no significant differences among the three varieties. The interactions of variety by harvesting treatment and variety by environment (site × year) were not significant. The material with the highest digestibility was harvested at the grain cut of GS and the grazing-stage cut of HC, particularly with the variety Morocco-628 (Table 3). Digestibility declined by 18.9 percentage units between the first grazing cut (tillering stage) and the milk stage. Material from the final cut of HC had the same digestibility as that from the H cut. Straw, particularly that of 48-Alger, had the lowest digestibility.

Table 1. Rainfall (mm) at the experimental sites.

Month	1988/89		1989/90		1990/91		1991/92		Average rainfall 1967–92	
	Laxia	Dromolaxia	Laxia	Dromolaxia	Laxia	Dromolaxia	Laxia	Dromolaxia	Laxia	Dromolaxia
September	0	0	37	0	0	0	0	0	6	2
October	10	32	38	26	2.0	2.0	25	31	22	19
November	75	21	2	36	2.2	26.5	32	60	31	42
December	102	90	36	40	10.2	23.2	180	328	58	85
January	142	76	10	61	31.3	46.0	3	5	48	68
February	5	19	105	84	37.4	48.0	75	81	47	58
March	16	44	23	37	59.8	58.4	14	12	37	39
April	0	0	9	6	4.5	26.8	4	18	22	18
May	0	0	0	0	0	0	15	39	22	9
June	0	0	0	0	0	0	0	0	7	2
July	0	0	0	0	0	0	0	0	1	0
August	0	0	0	0	0	0	0	0	7	1
Total	350	282	260	290	147	231	348	574	308	344
Barley mean yield (t/ha)	6.2	9.6	5.6	8.4	-	6.9	9.9	14.4	-	-

Table 2. Dry-matter yield, digestibility, digestible yield, nitrogen concentration and nitrogen yield over the site–year combinations, 1988–92 (number of sites as indicated).

Harvesting treatment†	Variety: Morocco-628	Kantara	48-Alger	Mean
Total dry matter harvested (t/ha) (7 sites)				
GS	9.07	8.70	9.66	9.14
H	9.71	9.46	8.98	9.38
HC	8.71	7.24	8.90	8.28
Mean	9.21	8.59	9.21	
SE ‡ (a) ± 0.366; (b) ± 0.633				
Percentage digestible organic matter in harvested dry matter (6 sites)				
GS	50.7	52.3	47.8	50.2
H	56.9	53.9	53.3	54.7
HC	58.8	58.2	55.2	57.4
Mean	55.1	54.4	51.7	
SE (a) ± 1.46; (b) ± 2.52				
Total digestible organic matter yield (t/ha) (6 sites)				
GS	4.68	4.85	4.70	4.74
H	6.10	5.49	5.40	5.66
HC	5.64	4.53	4.83	5.00
Mean	5.47	4.96	4.98	
SE (a) ± 0.213; (b) ± 0.368				
Percentage nitrogen in harvested dry matter (6 sites)				
GS	1.03	1.18	1.03	1.08
H	1.26	1.42	1.25	1.31
HC	1.68	1.78	1.55	1.67
Mean	1.28	1.42	1.24	
SE (a) ± 0.051; (b) ± 0.088				
Total nitrogen yield (kg/ha) (6 sites)				
GS	91	107	96	98
H	136	144	125	135
HC	166	146	145	153
Mean	127	131	119	
SE (a) ± 3.58; (b) ± 6.20				

† GS = grain and straw; H = milk-stage cut; HC = grazing-stage cut + milk-stage cut.

‡ SE (a) is for harvesting treatment and variety means; (b) for harvesting treatment × variety means.

The digestibility of Morocco-628 appeared to be a little higher at the individual cuts than that of the other varieties, except for grain which was similar for all three varieties (Table 3). The highest yield of digestible organic matter was obtained from the H followed by the HC and GS harvesting treatments (Table 2). The variety with the highest digestible organic-matter yield appeared to be Morocco-628 at harvesting treatment H. The material with the highest nitrogen concentration was harvested at the grazing-stage cuts of HC, particularly with Morocco-628 and 48-Alger (Table 3). Straw had, as expected, the lowest nitrogen concentration in all three varieties. Kantara had in all three harvesting treatments (weighted means) a little higher nitrogen concentration than the other two varieties (Table 2). The highest yields of nitrogen were, on average, produced by the HC harvesting treatment followed by H and then GS. The variety Morocco-628 produced at HC the highest nitrogen yield. The interaction of variety × environment (year × site) in the case of nitrogen concentration and nitrogen yield was not significant.

Results on the proportions and yields of green leaf, dead leaf, stem and inflorescence are shown in Tables 4, 5 and 6. The material with the highest proportion of green leaf blade was harvested at the grazing-stage cut of the HC harvesting treatment, and the lowest at the milk-stage cut of H and the final cut of the HC treatment (Tables 4 and 6), but in the case of dead leaf blade, the reverse was true. There were no significant differences in the proportion of green or dead leaf blade among the three varieties regardless of whether the harvesting treatments were averaged or examined individually. The proportion of stem was lowest at the grazing-stage cut of HC and increased with advancing crop maturity, particularly with Morocco-628 (Tables 4 and 6). There was no emerged inflorescence at the grazing-stage cut of the HC treatment; the proportion of inflorescence was highest at the final cuts of HC and H treatments, particularly with the variety 48-Alger.

The yield of green leaf blade was highest with the HC treatment and lowest with the H treatment, particularly with 48-Alger (Table 5). There was a significant effect of variety on the yield of dead leaf regardless of whether the varieties were averaged or examined individually. The yield of stem was highest with H, particularly with Kantara and 48-Alger, and lowest with HC, particularly with Kantara. The yield of emerged inflorescence was much greater in H than in HC; for H, the yield was higher with 48-Alger and Kantara than with Morocco-628.

On average, the number of plants which established was 257/m^2, and by the time of the first grazing-stage cut there were 779 tillers (including main stem)/m^2 (Table 7). The plants, therefore, had each produced on average two daughter tillers. The number of tillers was unaffected by harvesting since at the last count prior to the final harvest, there

Table 3. Dry-matter yield, digestibility, digestible yield, nitrogen concentration and nitrogen yield at the individual cuts over site–year combinations, 1988–92 (number of sites as indicated).

Variety	Harvesting treatment†				
	GS		H	HC	
	Grain	Straw	Hay cut	Grazing cut	Hay cut
	Dry matter harvested (t/ha) (7sites)				
Morocco-628	2.99	6.07	9.71	1.24	7.47
Kantara	3.63	5.07	9.46	1.33	5.91
48-Alger	3.44	6.22	8.98	1.06	7.85
SE (±)	0.070	0.161	0.303	0.040	0.260
Mean	3.35	5.79	9.38	1.21	7.08
	Percentage digestible organic matter in harvested dry matter (6 sites)				
Morocco-628	73.6	39.2	56.9	74.4	55.8
Kantara	74.6	36.6	53.9	72.5	53.9
48-Alger	71.3	34.7	53.3	71.7	52.4
SE (±)	1.15	0.84	0.85	0.64	0.65
Mean	73.2	36.8	54.7	72.9	54.0
	Digestible organic matter yield (t/ha) (6 sites)				
Morocco-628	2.26	2.42	6.10	1.10	4.55
Kantara	2.89	1.96	5.49	1.18	3.35
48-Alger	2.51	2.19	5.40	0.88	3.95
SE (±)	0.077	0.069	0.250	0.053	0.281
Mean	2.55	2.19	5.66	1.05	3.95
	Percentage of nitrogen in harvested dry matter (6 sites)				
Morocco-628	1.96	0.57	1.26	3.63	1.31
Kantara	1.92	0.65	1.42	3.36	1.39
48-Alger	1.84	0.58	1.25	3.60	1.21
SE (±)	0.055	0.037	0.097	0.064	0.059
Mean	1.90	0.60	1.31	3.53	1.30
	Nitrogen yield (t/ha) (6 sites)				
Morocco-628	58	33	136	53	113
Kantara	73	34	144	55	91
48-Alger	62	34	125	46	100
SE (±)	2.5	2.9	6.5	2.7	9.0
Mean	64	34	135	51	101

† GS = grain and straw; H = milk-stage cut; HC = grazing-stage cut + milk-stage cut.

were 37, 453 and 514 tillers/m^2 for GS, H and HC, respectively, i.e., for all these harvesting treatments there was a similar reduction of about 43% (range 41–45%) compared with the highest number recorded in the respective plots throughout the life of the crop. The two-row barley variety Kantara had the highest number of plants and tillers compared with the other two six-row barley varieties at the first and third counts and had a similar number of tillers/m^2 as 48-Alger at the second count.

Average plant height at the milk stage over the seven site × year combinations was significantly reduced when a grazing cut was taken prior to harvest for hay at the milk stage of grain, particularly in the case of Kantara and Morocco-628. The average height at harvest was 80 cm for treatment GS, 86 cm for H and 71 cm for treatment HC (SE ± 2.17). The tallest varieties were Morocco-628 and 48-Alger with 86 cm height, and the shortest was Kantara with 68 cm (SE ± 2.29).

Table 4. Green leaf, dead leaf, stem and inflorescence as percentage of the sown species on a dry-weight basis, mean of two environments.

Harvesting treatment†	Variety Morocco-628	Kantara	48-Alger	Mean
	Green leaf			
H	14.0	11.1	10.1	11.7
HC	24.9	22.9	21.6	23.3
Mean	19.4	17.0	15.8	
	SE (a)‡ ±1.64; (b) ±1.34; (c) ±2.32			
	Dead leaf			
H	4.9	7.7	6.2	6.3
HC	3.8	3.7	4.6	4.0
Mean	4.3	5.7	5.4	
	SE (a) ± 0.64; (b) ± 0.52 (c) ± 0.90			
	Stem			
H	57.3	52.7	48.5	52.8
HC	50.6	44.2	47.6	47.4
Mean	53.9	48.4	48.0	
	SE (a) ± 2.07; (b) ± 1.69; (c) ± 2.93			
	Inflorescence			
H	23.9	28.4	35.3	29.2
HC	20.8	29.3	26.2	25.4
Mean	22.3	28.8	30.7	
	SE (a) ± 2.04; (b) ± 1.67; (c) ± 2.89			

† H = milk-stage cut; HC = grazing-stage cut + milk-stage cut.
‡ SE (a) is for variety means; (b) for harvesting treatment means; (c) for variety × harvesting treatment means.

Discussion

The present results confirm earlier findings (Droushiotis 1984; Droushiotis and Wilman 1987) that in a typical Mediterranean climate, the utilization of barley for haymaking at a single harvest appears to be the most productive way of management. It was also confirmed that taking a hay cut at a single harvest, rather than first taking one grazing cut, allowed the development of a much heavier crop by the time of the final harvest, as would be expected (Droushiotis 1984), but at the expense of lower digestibility, nitrogen concentration and proportion of green leaf. With the HC treatment, yield at the final harvest was reduced by taking a grazing cut compared with not doing so (treatment H), but not to the same extent in all varieties. The variety 48-Alger is probably better able to recover after a grazing cut than the other two varieties, particularly Kantara which is an early-maturing variety, suggesting different uses for each variety. The rapid recovery of 48-Alger following defoliation may be attributed to the tendency of this variety to grow more prostrate at the early growth stages; a habit which prevents or limits the removal of shoot apices at the time of the cut, allowing the storage of readily available food reserves and hence the quick production of new leaf growth. Washko (1947) reported that except for rye, grain yield reductions caused by early grazing were related to growth habit.

On average, there was a large decline in crop digestibility and nitrogen concentration from the grazing to the milk stage, 18.9 and 2.23 percentage units, respectively. This is mainly due to the large decline in the proportion of green leaf blade between the grazing-stage cut (77.8%) and the hay cut (14%) and the increase in the proportion of stem from 22.1% in the case of the grazing cut to 51.3% in the hay cut (Table 6). Kantara had a higher proportion of stem

Table 5. Dry matter yields of green leaf, dead leaf, stem and inflorescence (t/ha), mean of two environments.

Harvesting treatment†	Variety Morocco-628	Kantara	48-Alger	Mean
	Green leaf			
H	1.9	1.7	1.4	1.7
HC	2.9	2.3	2.5	2.6
Mean	2.4	2.0	2.0	
	SE (a)‡ ± 0.25; (b) ± 0.20; (c) ± 0.35			
	Dead leaf			
H	0.7	1.3	0.9	1.0
HC	0.5	0.4	0.6	0.5
Mean	0.6	0.9	0.8	
	SE (a) ± .15; (b) ± 0.12 (c) ± 0.21			
	Stem			
H	7.9	8.2	6.6	7.6
HC	6.1	4.6	5.7	5.5
Mean	7.0	6.4	6.2	
	SE (a) ± 0.31; (b) ± 0.26; (c) ± 0.44			
	Inflorescence			
H	3.3	4.5	4.5	4.1
HC	2.4	3.0	2.9	2.8
Mean	2.8	3.7	3.7	
	SE (a) ± 0.25; (b) ± 0.20; (c) ± 0.35			

†, ‡ See Table 4.

Table 6. Dry matter yields of green leaf, dead leaf, stem and inflorescence and their percentages of the sown species on a dry weight basis at the individual cuts of the HC harvesting treatment, mean of two environments.

Variety	Crop fraction	Harvesting treatment HC					
		Grazing cut		Hay cut		Total	Weighted
		(t/ha)	(%)	(t/ha)	(%)	(t/ha)	mean (%)
Morocco-628	Green leaf	1.1	80.0	1.7	16.9	2.8	24.9
	Dead leaf	0	0	0.5	4.2	0.5	3.8
	Stem	0.3	20.0	5.9	55.0	6.2	50.6
	Inflorescence	0	0	2.4	23.9	2.4	20.8
	Total	1.4	100.0	10.5	100.0	11.9	100.0
Kantara	Green leaf	1.2	72.9	1.1	12.7	2.3	22.9
	Dead leaf	0	0.2	0.4	4.1	0.4	3.7
	Stem	0.5	26.9	4.2	47.3	4.7	44.1
	Inflorescence	0	0	3.0	35.9	3.0	29.3
	Total	1.7	100.0	8.7	100.0	10.4	100.0
48-Alger	Green leaf	1.2	80.5	1.3	12.6	2.5	21.6
	Dead leaf	0	0	0.6	5.2	0.6	4.6
	Stem	0.3	19.5	5.5	51.5	5.8	47.6
	Inflorescence	0	0	2.9	30.7	2.9	26.2
	Total	1.5	100.0	10.3	100.0	11.8	100.0
Mean	Green leaf	1.2	77.8	1.4	14.0	2.6	23.3
	Dead leaf	0	0.1	0.5	4.5	0.5	4.0
	Stem	0.3	22.1	5.1	51.3	5.4	47.4
	Inflorescence	0	0	2.8	30.2	2.8	25.4
	Total	1.5	100.0	9.8	100.0	11.3	100.0

(26.9%) at the grazing stage and a lower proportion at the milk stage (47.3%) compared with the other two varieties, 48-Alger (19.5 and 51.5%, respectively) and Morocco-628 (20 and 55%, respectively). This seems to reflect the earlier maturity of Kantara—more stem elongation at the grazing stage and more inflorescence at the hay stage. The slightly lower dry-matter yield obtained from the grain plus straw treatment (GS) compared with the milk-stage cut treatment (H) agrees with the growth curves of cereals (Milthorpe and Moorby 1974), where, during the ontogeny, there is first a period of accelerating growth rate followed by a period which is more or less constant, and then a declining rate, which actually becomes negative in the final weeks because the death of leaves and tillers exceeds the new grain growth. This situation becomes worse under the semiarid conditions of the Mediterranean region due to water stress at seed set (Wardlaw 1971).

Harvesting at the grazing-stage cut reduced plant height by 15 cm. Similar results were reported by Hadjichristodoulou (1983), Day et al. (1968), Droushiotis (1984) and Droushiotis and Wilman (1987). Droushiotis (1986) reported that the reduction in plant height in the grazed or clipped plants is mainly due to the reduction in length of the lower internodes. Tiller numbers were also reduced by about 41–45% for the three harvesting treatments after the peak was reached, regardless of whether there was a grazing-stage cut prior to final harvest (HC) or not (GS and H). Therefore, this reduction was not due to the harvest, but probably to some other factors. Droushiotis and Wilman (1987) reported that the number of tillers was on average little affected by the first grazing cut in October-sown plots, but was reduced by 68.5% by the first grazing cut in November-sown plots. However, Hadjichristodoulou (1983) and Droushiotis (1984), working with a number of barley varieties under similar conditions, reported that the number of tillers was not affected by grazing or cutting at an early growth stage. The difference among the various studies is probably due both to variation in grazing or cutting severity in relation to the position of the shoot apex at the time of grazing or cutting, and to environmental factors. In the present study, it is interesting to note that the percentage reduction in the number of tillers after the peak was reached was similar in all varieties in all three harvesting treatments. However, the lowest reduction was in the case of Kantara (23.9%) since this variety has a very high tillering capacity.

Table 7. Numbers of barley tillers/m², mean of seven site–year combinations, 1988/89–1991/92

Harvesting treatment†	Variety	When emergence was complete (10 January)‡	Immediately before first grazing cut of HC (2 March)‡	Immediately before milk stage cut of H or HC (14 April)‡ and grain cut of GS (15 May)‡§
GS	Morocco-628	175	499	265
	Kantara	239	793	538
	48-Alger	197	773	318
	Mean	204	688	374
H	Morocco-628	226	553	296
	Kantara	308	886	662
	48-Alger	291	862	402
	Mean	275	767	453
HC	Morocco-628	259	676	386
	Kantara	328	936	712
	48-Alger	292	1032	443
	Mean	293	882	514
Mean	Morocco-628	220	576	316
	Kantara	292	872	637
	48-Alger	260	889	384
	Mean	257	779	447
	SE (a)	± 8.70	± 28.3	± 11.5
	SE (b)	± 14.3	± 46.6	± 19.9

† GS = grain and straw; H = milk-stage cut; HC = grazing-stage cut + milk-stage cut.
‡ Approximate date of count.
§ The results in this column are from five site–year combinations.
SE (a) is for variety and harvesting treatment means; (b) for harvesting treatment × variety means.

It can be concluded that in low-rainfall environments, the maximum dry-matter production from barley is obtained from a single cut either at the milk stage of grain or when the crop is harvested for grain and straw. However, farmers' decisions to allow green-stage grazing are influenced by a mix of socioeconomic and agronomic factors. An example of the complexity of the trade-off decision made by farmers is a model developed by economists at ICARDA (1983) which shows that under high-rainfall conditions, light grazing of green barley could improve the value of the mature crop by reducing lodging and increasing the number of tillers. Conversely, heavy and repeated grazing could cause the loss of what otherwise would have been an excellent grain crop. On the other hand, in a very dry year, even light grazing could reduce the mature harvest value of the barley crop. Therefore, from the farmers' point of view, it may be advisable to apply the following management practice: in areas where forage production is restricted by low rainfall to the six months from October to April, and where forage is usually in short supply early in the season when animal requirements are high, a good alternative is the HC harvesting treatment which provides an early cut or grazing to take advantage of the high proportion of green leaf, hence, higher nitrogen concentration and digestibility of this forage and then an aftermath hay cut. In areas where farmers are thinking largely in terms of high total yield, harvesting treatments H and GS are recommended. Alternatively, it may be advisable to utilize part of the area with the HC harvesting treatment and the rest of the barley area could be left mainly for hay or grain and straw.

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Effect of Sowing Date on Yield of Food-Barley Varieties in Northwestern Ethiopia

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Abstract

An experiment was conducted during the main seasons of 1990, 1992 and 1993 in northwestern Ethiopia to determine the optimum sowing date for three food-barley (*Hordeum vulgare* L. subsp. *vulgare)* varieties. Results indicated that early planting during the growing season results in higher grain yield and that the optimum sowing date is between late May to mid-June.

Key words: *Hordeum vulgare*; sowing date; planting date; grains; yield increases; Ethiopia.

تأثير موعد الزراعة على غلة أصناف من الشعير – تُستخدم في غذاء الانسان – في شمال غربي إثيوبيا

الملخص

أجريت تجربة خلال المواسم الرئيسية للأعوام 1990، 1992، 1993 في شمال غربي إثيوبيا لتحديد موعد الزراعة الأمثل لثلاثة أصناف من الشعير (*Hordeum vulgare* L. subsp. *vulgare*) تُستخدم كغذاء للإنسان. وقد أشارت النتائج إلى أن الزراعة المبكرة خلال الموسم الزراعي تُسفر عن غلة حبية أعلى وأن موعد الزراعة الأمثل هو الذي يتم بين أواخر أيار/مايو ومنتصف حزيران/يونيو.

Introduction

Barley is one of the most important cereal crops grown in northwestern Ethiopia. It is second to tef both in area and annual production in the region (CSA 1987, 1989). It has a wide range of utilization; it is used as a major staple food and its by-products are important as animal feed. Currently, barley occupies up to 15% of the total cropland around Bahir Dar, Mecha and Adet (Aleligne and Franzel 1987; Aleligne and Regassa 1989). Despite its multipurpose uses, average productivity at the farm level is as low as 9 q/ha (900 kg/ha) (CSA 1987, 1989). One of the several factors causing this low productivity is the lack of improved agronomic techniques. Among these, sowing date has a considerable bearing on yield and is frequently a determining factor in the success or failure of the crop. Results of sowing date trials conducted at Holetta Research Center of the Institute of Agricultural Research (IAR) showed that the optimum sowing date for planting barley is 15–25 June (Fekadu 1987). This paper summarizes the results of trials conducted to determine the optimum sowing date for three food-barley varieties under the environmental conditions of Adet.

Material and Methods

The experiment was conducted during the main seasons of 1990, 1992 and 1993 on the nitosols of Adet experimental site (of altitude of 2240 m asl) using three varieties: HB-100, HB-99 and Adet local. Seeds were sown at the rate of 100 kg/ha in 20-cm-apart rows using fertilizer at the rate of 60 kg N and 60 kg P_2O_5/ha. Six sowing dates were used: 26

May, 5, 15 and 25 June, and 5 and 15 July. The experimental design was a split-plot in randomized complete blocks with three replications; varieties and sowing dates were assigned to the main and sub-plots, respectively. Each sub-plot measured 2.2 × 5 m and consisted of 11 rows.

Data were collected on grain yield, plant height, days to heading and maturity, biomass weight and straw yield. Yield data were obtained from the central seven rows in each sub-plot. The data were then subjected to analysis of variance.

Results and Discussion

The analysis of variance indicated that there were significant differences in grain yield ($P < 0.01$) due to variety in 1990 and 1993. Those due to sowing date were significant in all years and those due to the interaction of sowing date and variety were significant in 1990 and 1992 (Table 1). In 1992, the highest mean grain yield (28.67 q/ha or 2,867 kg/ha) and the highest yields for each variety and sowing date were obtained. This is due to the large amount and good distribution of rainfall during that year (Fig. 1).

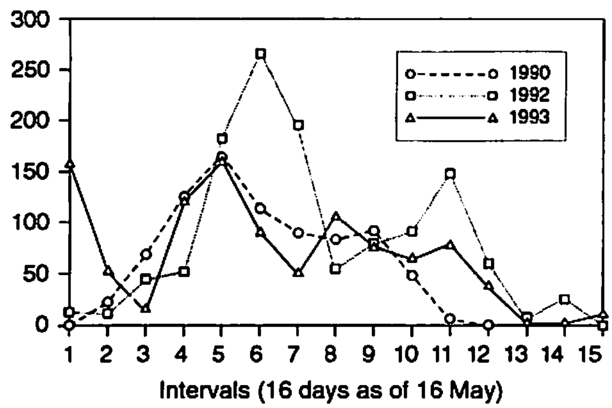

Fig. 1. Bi-weekly rainfall data, Adet.

The combined analysis over the three years indicated that there were significant grain yield differences ($P < 0.05$) due to sowing date and due to the interaction of sowing date and variety ($P < 0.01$). No significant yield differences were detected between varieties (Table 2).

A significant linear decline in average grain yield occurred with delayed planting. The highest grain yields of 25 and 24 q/ha (2,500 and 2,400 kg/ha) were obtained from the 26 May and 5 June planting, respectively. The optimum sowing date was 26 May for variety HB-99 and 5 June for HB-100 and Adet local, with respective grain yields of 28, 29 and 20 q/ha (2,800, 2,900 and 2,000 kg/ha, respectively).

Table 1. Effect of sowing date on grain yield (q/ha)† of three food-barley varieties.

Sowing date	1990	1992	1993									
	V1‡	V2	V3	Sowing date mean	V1	V2	V3	Sowing date mean	V1	V2	V3	Sowing date mean
26 May	27.63	18.70	16.77	21.03	32.51	35.12	25.29	30.97	23.50	29.57	15.46	22.84
5 June	29.94	17.20	18.20	21.78	35.11	30.79	24.74	30.21	22.34	23.15	16.68	20.72
15 June	27.78	17.33	19.03	21.38	34.03	34.51	25.63	31.39	15.27	16.30	8.51	13.36
25 June	18.98	15.54	18.20	17.57	34.80	35.93	24.07	31.60	18.81	19.17	9.46	15.81
5 July	18.85	16.97	19.29	18.37	24.04	30.69	25.59	26.77	10.90	19.05	12.00	13.98
15 July	19.88	10.61	16.45	15.65	16.92	24.35	21.97	21.08	16.73	18.79	9.89	15.14
Variety mean	23.84	16.06	17.99	19.30	29.57	31.90	24.55	28.67	17.93	21.01	12.00	16.98
	Variety				Sowing date				Variety × sowing date			
	1990	1992	1993		1990	1992	1993		1990	1992	1993	
LSD (5%)	4.09	ns	4.28		1.75	3.32	2.89		3.03	5.74	ns	
LSD (1%)	ns	ns	7.10		2.34	4.47	3.89		4.08	7.73	ns	
CV (%)	22.89	30.77	27.26		9.45	12.01	17.66					

† q = quintal, 1 q = 100 kg; ‡ V1 = HB-100; V2 = HB-99; V3 = Adet local.; ns = not significant.

Table 2. Grain yield performance (q/ha)† of food barley as affected by sowing date and variety over years.

Sowing date	Variety			Sowing date mean
	HB-100	HB-99	Adet local	
26 May	17.88	27.80	19.17	24.95
5 June	29.13	23.72	19.87	24.24
15 June	25.67	22.71	17.72	22.04
25 June	24.20	23.55	17.24	21.67
5 July	17.93	22.24	18.96	19.71
15 July	17.84	17.92	16.10	17.29
Variety mean	23.78	22.99	18.81	
	Variety	Sowing date	Variety × sowing date	
LSD (5%)	ns	1.88	2.66	
LSD (1%)	ns	ns	3.52	
CV (%)	29.06	13.11		

† q = quintal, 1 q = 100 kg.
ns = not significant.

Varietal differences in days to heading and maturity were significant, whereas sowing date and the interaction of sowing date and variety were not significantly affected in both years. Plant height and straw yield were not significantly affected by either of the factors in both years.

Conclusions

From this study it may be concluded that (1) early planting during the growing season results in higher grain yield for varieties HB-100 and HB-99, (2) the optimum sowing time is between late May and mid-June for both varieties, and (3) HB-100 and HB-99 are superior to the local variety in terms of grain yield.

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Combining Ability Studies for Some Physio-morphic Characters in Wheat

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Abstract

Combining ability studies were made using a line × tester analysis involving six wheat (*Triticum aestivum* L. subsp. *aestivum*) lines, HABA 7, HABA 9, HABA 20, LABA 7, LABA 9 and LABA 20 (used as female parents), and three varieties Pak. 81, K-1595 and LU26S (used as male parents). Data for osmotic pressure, stomatal size, hydrophilic colloids, inter-nodal length and grain yield per plant were recorded. Among testers,

دراسات قدرة التوافق لبعض الصفات الفيزيائية - الشكلية في القمح

الملخص

أجريت دراسات المقدرة التوافقية باستخدام تهجينات بين سلالة ما x سلالات مختبرة سابقاً، شملت ست سلالات من القمح (*Triticum aestivum* L. subsp. *aestivum*)، هي: HABA7، HABA9، HABA20، LABA7، LABA9 وLABA20 (استخدمت كأمهات) وثلاثة أصناف، هي: Pak. 81، K-1595 و LU26S (استخدمت كآباء). وقد سجلت البيانات عن الضغط الحلولي، حجم الثغيرات، المواد الغراوانية المحبة للماء، الطول ما بين عقدتين على الساق، والغلة الحبية لكل نبات. ومن بين المجموعة المختبرة، كان Pak 81 أفضل متوافق عام بالنسبة للصفات المدروسة. وقد وصفت معظم الهجن بما فيها سلالات HABA والصنفان Pak 81 وLU26S التأثيرات الملائمة لقدرة التوافق الخاصة (SCA). لذلك يُقترح استخدام سلالات HABA في عمليات التحسين المستقبلية للصفات الفيزيائية - الشكلية في القمح.

Pak. 81 was the best general combiner for the traits studied. Most of the hybrids involving HABA lines, and varieties Pak. 81 and LU26S depicted suitable specific combining ability (SCA) effects. Therefore, use of HABA lines is suggested for future improvement of drought-related physio-morphic characters in wheat.

Key words: wheats; combining ability; hybrids; agronomic characters; drought stress; drought resistance; ABA; plant anatomy; plant physiology; Pakistan.

Introduction

Abscisic acid (ABA) is a growth hormone which may reduce water loss from the plants causing stomatal closure. Growth of plants is also enhanced so that they may escape drought conditions by completing their life cycle earlier. There is evidence that ABA normally plays a role in the resistance of mesophytes to water stress. Most studies have been done with drought-sensitive and drought-resistant cultivars of crop plants, like those of Quarrie (1980) who observed that resistant cultivars had higher levels of ABA when they were exposed to stress. The association of ABA accumulation and stomatal closure, as leaves are stressed for moisture, is of great interest to physiologists. The formation of ABA during stomatal closure seems to validate the theory of ABA as the triggering mechanism in stomatal control (Dorffling 1972). It is released from chloroplast in the epidermal cells during moisture stress and is translocated in guard cells. To develop high-yielding drought-resistant varieties, better understanding will be necessary for various morphophysiological attributes that are helpful in situations of water stress at different stages of plant growth.

The significant role of ABA for controlling stomatal movements initiated the use of wheat lines with varying levels of ABA. High and low ABA lines were thus used in this study for evaluation of combining ability effects for some morphophysiological traits closely related to stress tolerance.

Material and Methods

In 1990, six wheat lines (High ABA 7, High ABA 9, High ABA 20, Low ABA 7, Low ABA 9 and Low ABA 20, used as female parents) were crossed with Pak. 81, K-1595 and LU26S (male parents) to produce F_1 seed. The following year, F_1 seeds along with their parents were space-planted in a randomized complete block design with three replications. Each replication consisted of nine parents and their 18 F_1 crosses in a 5-m-long single row. Spacing between plant to plant and row to row was kept at 15 and 30 cm, respectively. The experimental population was kept under normal agronomic care from sowing to maturity. Data were collected on osmotic pressure, stomatal size, hydrophilic colloids, inter-nodal length and grain yield per plant. The data were statistically analyzed and combining ability studies were made using line × tester analysis as described by Kempthrone (1957).

Results and Discussion

Analysis of variance (Table 1) revealed significant differences among genotypes (parents and crosses) for stomatal size, inter-nodal length and grain yield per plant, while the differences were non-significant for osmotic pressure and hydrophilic colloids. Significant differences for inter-nodal

Table 1. Analysis of variance for all the traits studied.

Source	df	Osmotic pressure	Stomatal size	Hydrophilic colloids	Inter-nodal length	Grain yield/plant
			Mean squares			
Replications	2	1402.82 ns	97700.11 ns	0.0014 ns	0.65 ns	3348.53**
Genotypes	26	850.03 ns	267802.80*	0.00075 ns	7.69**	700.07*
Parents (P)	8	749.75 ns	349684.66*	0.0005 ns	10.21**	900.91**
P vs C	1	1908.25 ns	22050.00 ns	0.0003 ns	0.02 ns	1850.88**
Crosses (C)	17	835.44 ns	243726.23 ns	0.0009 ns	6.96**	537.86 ns
Lines (L)	5	561.54 ns	163157.82 ns	0.0009 ns	12.80**	895.85*
Testers (T)	2	1454.68 ns	713728.66*	0.0003 ns	9.87**	142.28 ns
L × T	10	848.55 ns	189989.95 ns	0.0009 ns	3.45**	438.10 ns
Error	52	630.17	150907.20	0.0007	0.78	373.26

*, ** significant at $P \leq 0.05$ and 0.01, respectively.
ns = not significant.

length and grain yield per plant were observed in lines (females), while testers (males) depicted significant differences for stomatal size and inter-nodal length. Interaction of lines and testers was significant only in case of inter-nodal length. Mean values of parents and crosses for the characters under study are presented in Tables 2 and 3, respectively. Among parents, LABA 7 had the smallest stomata while HABA 20 had the largest.

Transpiration (water loss from plant) mainly occurs through stomata. As stomata open wider, more water is lost. Stomata size is affected by both genotype and environment. Genotypes with smaller stomata are useful under droughty environments to reduce water loss via transpiration. Hybrids presented increased vigor for stomatal size thereby increasing over the mean of their respective parents. The smallest stomata were observed in the hybrid HABA 7 × Pak. 81 which showed 13.2% decrease over the mean of its parents. Inter-nodal length was maximum in male parent LU26S, while the minimum value was observed in female parent LABA 20. In case of hybrids, maximum and minimum values for inter-nodal length were observed in HABA 9 × LU26S and LABA 7 × Pak. 81 hybrids, respectively. Under droughty conditions, shorter plants are suitable because they are more responsive to fertilizer and escape from lodging.

Table 2. Mean values of the traits studied for the parents.

Parent	Osmotic pressure (mOsm kg^{-1})	Stomatal size (μm^2)	Hydrophilic colloids (g)	Inter-nodal length (cm)	Grain yield/ plant (g)
Male					
Pak. 81	370.0	2042	0.126	19.10	28.70
K-1595	370.7	2057	0.119	22.30	22.40
LU26S	365.0	1774	0.142	23.33	23.80
Mean	368.6	1957.67	0.129	21.58	24.97
SD (±)	3.1	159.24	0.012	2.21	3.31
Female					
HABA 7	412.7	2035	0.104	18.76	18.45
HABA 9	375.7	2200	0.101	22.83	20.95
HABA 20	374.0	2697	0.131	21.60	18.05
LABA 7	366.7	1542	0.118	19.13	17.40
LABA 9	392.7	2268	0.114	20.80	21.52
LABA 20	365.7	2437	0.128	18.70	17.49
Mean	381.3	2196.50	0.116	20.30	18.98
SD (±)	18.2	391.90	0.012	1.71	1.80

SD = standard deviation (deviation from the mean of the genotypes).

Grain yield per plant was maximum in Pak. 81, while the lowest value was observed in LABA 7. Among hybrids, maximum yield per plant was observed in LABA 9 × Pak. 81. This hybrid showed increased vigor over its better parent Pak. 81, which might be due to complementary action of genes for grain yield.

Table 3. Mean values of the traits studied for the crosses.

Cross	Osmotic pressure (mOsm kg^{-1})	Stomatal size (μm^2)	Hydrophilic colloids (g)	Inter-nodal length (cm)	Grain yield/ plant (g)
HABA 7 × Pak. 81	356.7	1767	0.106	20.06	26.91
HABA 7 × K-1595	361.0	1864	0.105	23.06	24.49
HABA 7 × LU26S	387.7	2444	0.113	19.80	20.99
HABA 9 × Pak. 81	393.3	2289	0.120	22.40	21.19
HABA 9 × K-1595	359.0	2493	0.125	22.90	19.87
HABA 9 × LU26S	370.3	2134	0.125	23.90	20.09
HABA 20 × Pak. 81	349.7	2281	0.132	19.90	21.29
HABA 20 × K-1595	381.0	2162	0.160	20.80	21.29
HABA 20 × LU26S	368.3	2216	0.120	19.80	20.33
LABA 7 × Pak. 81	352.0	2216	0.155	18.20	22.56
LABA 7 × K-1595	354.3	2016	0.160	20.50	23.96
LABA 7 × LU26S	360.0	2338	0.101	19.60	23.85
LABA 9 × Pak. 81	349.6	1922	0.114	19.03	29.28
LABA 9 × K-1595	371.0	1837	0.122	19.46	23.42
LABA 9 × LU26S	407.3	2252	0.130	21.80	21.78
LABA 20 × Pak. 81	347.0	1877	0.148	19.40	17.05
LABA 20 × K-1595	378.0	2106	0.111	20.80	20.42
LABA 20 × LU26S	354.3	2880	0.140	21.30	21.50
Mean	366.7	2171.89	0.127	20.71	22.24
SD (±)	16.96	275.74	0.019	1.56	2.79

SD = standard deviation (deviation from the mean of the genotypes).

Combining ability analysis

The ability of an inbred line/true breeding plant to transmit desirable performance to the hybrid progeny is referred to as its combining ability. General and specific combining ability effects for the characters under study are presented in Tables 4 and 5, respectively. Under moisture-stress conditions, the genotypes with high osmotic pressure in their cells, i.e., with higher concentrations of solutes, can survive better because this higher concentration of solutes will help them to drag out more water from the soil via roots. Therefore, positive combining ability effects for osmotic pressure are useful. Male parent LU26S and female parent LABA 9 depicted the highest general combining ability (GCA) effects (Table 4). F_1 cross of these two parents also presented a high positive specific combining ability (SCA) effect (Table 5). Therefore LABA 9 × LU26S could be considered for improvement of this character in wheat.

Many crops like wheat have numerous stomata on both sides of their leaves. Stomata number and size, which are affected by both genotype and environment, have much less effect on total transpiration than stomatal opening and closing (Gardner et al. 1985). As stomata open wider, more water is lost. Therefore, the size of stomatal opening should be minimum. Moreover, the plants with smaller stomatal openings can efficiently and economically regulate water loss from the plant. In this case, negative effects are desirable. Pak. 81 in male parents and LABA 9 in female parents depicted the highest negative GCA effects. However, F_1 of these parents showed positive SCA effects for this character. This might be due to a complementary action of genes for stomatal size or to the effect of the environment. Worth-mentioning crosses with high negative SCA effects are HABA 9 × LU26S followed by LABA 20 × Pak. 81 and HABA 20 × LU26S. These crosses may be considered for further studies.

Table 4. General combining ability (GCA) effects for the traits studied.

Parents	Osmotic pressure	Stomatal size	Hydrophilic colloids	Inter-nodal length	Grain yield/ plant
Tester					
Pak. 81	–8.648	–152.78	0.006	–0.852	2.900
K-1595	–0.648	–72.45	–0.003	0.493	–0.185
LU26S	9.296	225.23	–0.003	0.359	–2.715
SE	35.501	549.38	0.037	1.249	27.322
Line					
HABA 7	1.741	–127.00	–0.017	0.276	8.048
HABA 9	7.519	153.10	–0.0007	2.207	–7.285
HABA 20	–0.371	67.34	0.014	–0.491	–4.196
LABA 7	–8.593	–80.44	–0.003	–1.245	5.145
LABA 9	9.296	–147.89	–0.002	–0.580	12.071
LABA 20	–9.593	134.89	0.009	–0.168	–13.783
SE	25.103	388.47	0.026	0.883	19.320

Plants with greater quantities of hydrophilic colloids can absorb moisture for longer periods and can be more successfully grown in drought conditions. Female lines HABA 20 and LABA 20 depicted positive GCA effects for

Table 5. Specific combining ability (SCA) effects for the traits studied.

Cross	Osmotic pressure	Stomatal size	Hydrophilic colloids	Inter-nodal length	Grain yield/ plant
HABA 7 × Pak. 81	–3.13	–104.89	–0.0070	–0.06	9.92
HABA 7 × K–1595	–6.80	–88.88	–0.0006	1.60	2.51
HABA 7 × LU26S	9.93	193.77	0.0076	–1.54	–12.43
HABA 9 × Pak. 81	27.76	136.66	–0.0085	0.38	–3.08
HABA 9 × K–1595	–14.58	260.00	0.0043	–1.00	–5.28
HABA 9 × LU26S	–13.19	–396.66	0.0042	0.62	8.36
HABA 20 × Pak. 81	–8.02	114.80	–0.0103	0.61	–2.63
HABA 20 × K–1595	15.32	115.10	0.0248	0.16	2.78
HABA 20 × LU26S	–7.30	–229.90	–0.0145	–0.77	–0.15
LABA 7 × Pak. 81	2.54	–58.12	0.0294	–0.40	–7.62
LABA 7 × K–1595	–3.13	16.88	–0.0116	0.55	2.86
LABA 7 × LU26S	0.60	41.24	–0.0177	–0.15	4.76
LABA 9 × Pak. 81	–17.69	70.66	–0.0133	–0.24	19.37
LABA 9 × K–1595	–4.35	–94.67	0.0024	–1.15	–6.86
LABA 9 × LU26S	22.04	24.01	0.0109	1.39	–12.51
LABA 20 × Pak. 81	–1.46	–259.12	0.0095	–0.28	–15.95
LABA 20 × K–1595	13.54	–108.78	–0.0191	–0.16	4.00
LABA 20 × LU26S	–12.08	367.90	0.0096	0.44	11.95
SE	14.49	224.28	0.0153	0.51	11.15

hydrophilic colloids. The highest SCA effect (0.0294) was observed in the cross LABA 7 × Pak. 81. Other notable crosses are HABA 20 × K-1595 and LABA 9 × LU26S.

Shorter plants are more responsive to fertilizer and tolerant to lodging. Therefore, more emphasis is given to the selection of short-stature plants. Short inter-nodal length will result in short plants. Among parents, LABA 7 and Pak. 81 presented high negative GCA effects. In case of crosses, the highest negative SCA effects for inter-nodal length were observed in HABA 7 × LU26S.

Under drought conditions, yield is the most affected trait. Water-stress conditions cause stomatal closure thereby reducing CO_2 uptake and fixation, causing severe reduction in photosynthesis rate and dry-matter accumulation. As a consequence, yield is ultimately affected. Among parents, LABA 9, HABA 7 and LABA 7 depicted positive GCA effects for grain yield. Crosses showing positive SCA effects were LABA 9 × Pak. 81 followed by LABA 20 × LU26S and HABA 7 × Pak. 81. Although the ultimate aim of the breeder is to obtain more yield, for droughty conditions the selection criterion should be drought tolerance. The role of ABA in drought tolerance is quite significant. During water stress, ABA begins to increase markedly in leaf tissues and, to a lesser extent, in other tissues including roots (Bradford and Hsiao 1982; Salisbury and Marinos 1985). This leads to stomatal closure and reduced transpiration. In addition, ABA inhibits shoot elongation further conserving water, and root growth is promoted which could increase water supply. There is also evidence that suitable concentrations of ABA increase the rate of conductance through roots which would reduce water stress in shoots. Often, drought-tolerant cultivars have higher levels of ABA, with some exceptions (Salisbury and Ross 1986).

According to these facts and the results of this study it is suggested to use HABA lines for the improvement of drought-related characters. Most of the hybrids involving HABA lines, particularly HABA 9, depicted suitable SCA effects for the traits under consideration. Suitable testers showing good GCA effects were Pak. 81 and LU26S.

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Inheritance of Spike Area in Three Inter-varietal Durum-Wheat Crosses under Different Environments

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Abstract

Parental, F_1, F_2, B_1, B_2, B_{11}, B_{12}, B_{21}, B_{22}, B_1 self and B_2 self generations of three crosses involving six cultivars of durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) were studied for spike area under normal

توريث حجم السنبلة في ثلاثة تهجينات بين أصناف من القمح القاسي تحت بيئات مختلفة

الملخص

تمت دراسة الآباء، الجيل الأول F_1، الجيل الثاني F_2، B_1، B_2، B_{11}، B_{21}، B_{22}، وجيلي B_1 و B_2 الملقحين ذاتياً لثلاثة تهجينات شملت ستة أصناف من القمح القاسي (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) للتعرف على حجم السنبلة تحت ظرفيّ الزراعة في موعد مألوف وموعد متأخر. وقد فسّر نموذج المعايير الستة تحت الزراعة في موعد مألوف ونموذج المعايير العشرة تحت الزراعة في موعد متأخر، الاختلافات في متوسطات الأجيال في معظم الحالات بصورة

and late sowing. The six-parameter model under normal sowing and ten-parameter model under late sowing adequately accounted for the variability in generation means in most cases. The additive (d) effects were generally more important than dominance (h) effects. However, one or the other digenic and trigenic, epistatic effects were significant, but the relative significance of epistatic effects varied among crosses and environments. Absolute totals of non-fixable gene effects were much higher than those of fixable effects in both environments, indicating the greater role of non-additive effects in controlling the inheritance of spike area. Significant heterosis was attributed by the major combined effects of dominance (h) effect and additive × dominance × dominance (Y) epistatic interaction. Restricted recurrent selection, biparental mating and diallel selective mating methods, which exploit both fixable and non-fixable components, have been suggested for the improvement of this trait. Furthermore, the plant material should be evaluated under normal sowing for more effective improvement of this trait.

Key words: *Triticum durum*; spikes; hybridization; genetic inheritance; dimensions; surface area; genotype environment interaction; sowing date; environment; India.

كافية. وكانت التأثيرات التجميعية (d) بشكل عام أكثر أهمية من تأثيرات السيادة (h). ومع ذلك كانت تأثيرات مورثة أحادية أو مورثة ثنائية أو ثلاثية، أو التأثيرات غير الأليلية، معنوية، إلا أن الأهمية النسبية للتأثيرات غير الأليلية تباينت بين الهجن والبيئات. وكان المجموع الكلي للتأثيرات غير المستقرة للمورثات أعلى بكثير من تلك التأثيرات المستقرة في كلتا البيئتين، مما يشير إلى دور أكبر للتأثيرات غير التجميعية في التحكم بتوريث حجم السنبلة. وتعزى قوة الهجين إلى التأثيرات المركبة الرئيسية لتأثير السيادة (h) والتفاعلات غير الأليلية السائدة (Y) x التجميعية x السيادية. ومن أجل تحسين هذه الصفة، اقترحت طرائق الانتخاب الرجعي المحدود والتهجين الثنائي الأب والتهجين الانتقائي الثنائي الأليل التي تستغل المكونات المستقرة وغير المستقرة على السواء. وعلاوة على ذلك، يتعين تقييم المادة النباتية تحت ظروف الزراعة في موعد مألوف بغية تحقيق المزيد من تحسين هذه الصفة بشكل فعّال.

Introduction

Recent studies have indicated that selection for morphophysiological characters is a promising method of producing high-yielding cultivars (Donald 1968; Hsu and Walton 1970; Yap and Harvey 1972; Bhatt 1976; Dhindsa 1982). Although the influence of some morphophysiological traits on the yielding ability is known, information regarding their inheritance is lacking, particularly in durum wheat. Thus, identification of such yield components and knowledge of their genetic control should enable breeders to maximize grain yield. In wheat, spike area is considered an important morphophysiological trait, as it is the source of assimilates to the caryopsis, contributing about 20–30% of the dry matter accumulated in the kernels (Thorne 1965). Therefore, this study aimed to investigate the inheritance of spike area in durum wheat in different environments.

Material and Methods

The experimental material was generated from three crosses, namely Cocorit 71 × A-9-30-1, HI 8602 × JNK-4W-128 and Raj 911 × DWL 5002. Twelve generations—parental, F_1, F_2, first backcross and its self raised generations (B_1, B_2, B_{1s} and B_{2s}) and second backcross generations (B_{11}, B_{12}, B_{21} and B_{22})—of each of the three crosses were produced. The experiment was grown in a randomized block design with three replications. Rows were 5 m long, with row-to-row distance of 30 cm and plant-to-plant distance of 15 cm under both normal and late sowing. Plots comprised two rows for parents and F_1s, four rows for backcross generations, and six rows for F_2, B_{1s} and B_{2s} generations. The study was based upon 15 randomly selected plants in each of P_1, P_2 and F_1; 30 plants in backcross generations, and 60 plants in F_2 and self-backcross generations.

The length and diameter at the middle of the main spike of each sampled plant were measured and the area was calculated following Yap and Harvey (1972). The appropriate model and estimates of gene effects were calculated for each cross in each environment by the joint scaling test (Cavalli 1952). Components of heterosis in the presence of digenic and trigenic interactions were calculated following Jinks and Jones (1958) and Hill (1966), respectively.

Results and Discussion

The results of the Chi-square test indicated that the ten-parameter model was the most appropriate to explain variability among the 12 generation means of the crosses, HI 8062 × JNK-4W-128 and Raj 911 × DWL 5002 under late sowing. In normal sowing, the six-parameter model was found more appropriate (Table 1). This confirmed that epistatic interactions might be important in controlling the inheritance of spike area. The results indicated that the plant material should be evaluated under normal sowing for more effective improvement of this trait, because late sowing may result in non-significant differences among the generations (Cocorit 71 × A-9-30-1) or a more complex inheritance of the character.

Additive (d) effects were generally more important than dominance (h) effects, except in the cross HI 8062 × JNK-4W-128 in normal sowing where none of the main effects was significant. However, either digenic or trigenic epistatic effects were significant, but the relative significance of epistatic effects varied among crosses and environments (Table 1).

The absolute totals of the epistatic effects (Table 2) indicated that the second-order interactions were higher than the first-order interactions and the main effects in late sowing of the crosses HI 8062 × JNK-4W-128 and Raj 911 × DWL 5002. Under normal sowing, first-order interactions were higher than the main effects in all the crosses, except Cocorit 71 × A-9-30-1, where main effects were slightly higher, though epistatic effects were also significant and important.

The results of this study are in agreement with the findings of Thombre (1977), Dhindsa (1982) and Singh (1982), who also observed predominance of epistatic effects involved in controlling the inheritance of spike area in wheat. The sum totals of the non-fixable effects were higher than those of the fixable effects, further indicating the

Table 1. Results of joint scaling test and gene effects for spike area (cm^2) in wheat grown under different environments.

Gene effects†	Cocorit 71 × A-9-30-1	HI 8062 × JNK-4W-128		Raj 911 × DWL 5002	
	NS‡	NS	LS	NS	LS
m	29.75**	29.55**	28.69**	31.37**	31.85**
	± 0.83	± 1.97	± 1.17	± 2.01	± 1.25
(d)	−0.90*	−0.66	−2.97**	5.04**	6.49**
	± 4.41	± 0.77	± 0.75	± 0.45	± 1.21
(h)	6.78**	4.82	6.05**	3.92	1.49
	± 1.31	± 2.78	± 1.52	± 2.74	± 2.42
(i)	3.43**	2.79	2.09	2.40	8.49**
	± 1.29	± 2.83	± 3.62	± 2.81	± 1.93
(j)	1.95	−1.04	−5.98	4.84**	9.94
	± 1.31	± 1.93	± 3.36	± 1.02	± 5.36
(l)	−0.23	−9.33	−10.83	1.10	19.91
	± 2.85	± 4.44*	± 12.28	± 3.85	± 11.04
(W)			−4.63	−	0.63
			± 2.87		± 4.99
(X)			−5.10		28.26*
			± 15.55		± 11.64
(Y)			−20.54**		0.89
			± 7.47		± 12.08
(Z)			4.18		−17.79
			± 17.51		± 19.63
Chi-square value of appropriate model (df)	2.74 (6)	6.06 (6)	21.70 (2)	7.33 (6)	6.89 (2)

† m = mean of all possible homozygous lines; (d) = additive gene effects pooled over all loci; (h) = dominance gene effects pooled over all loci showing dominance; (i) = overall additive × additive epistatic gene effects; (j) = overall additive × dominance epistatic gene effects; (l) = overall dominance × dominance epistatic gene effects; (W) additive × additive × additive gene interaction effects = ; (X) additive × additive × dominance gene interaction effects = ; (Y) = additive × dominance × dominance gene interaction effects; (Z) = dominance × dominance × dominance epistatic gene interaction effects.

‡ NS = normal sowing; LS = late sowing.

*, ** significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.

importance of epistatic effects in controlling the inheritance of spike area (Table 2). However, the type of the epistatic could not be ascertained.

Analysis of components of heterosis revealed that dominance (h) effect and additive × dominance × dominance (Y) epistatic interaction had a major role in causing significant heterosis (HI 8062 × JNK-4W-128, late-sown). Positive and significant inbreeding depression was observed in two cases, due to the dissipation of non-additive dominance effects or epistatic effects involving dominance in the F_2 generation. The absence of heterosis in the crosses could be explained by the internal cancellation of components of heterosis (Table 3).

The present study indicated the predominance of non-additive effects in the inheritance of spike area in both normal and late-sowing environments. Therefore, the non-conventional breeding methods such as restricted recurrent selection, biparental mating and diallel selective methods would more usefully exploit the non-additive effects for further improvement in the spike area in durum wheats. However, an appropriate choice of the environment for a simpler inheritance of this trait may be considered.

Table 2. Absolute totals of epistatic effects and fixable and non-fixable gene effects for spike area under normal and late sowing.

Cross	Environment	Main effects†		Absolute totals of epistatic effects		Absolute totals of gene effects	
		(d)	(h)	1st order interactions	2nd order interactions	Fixable	Non-fixable
Cocorit 71 × A-9-30-1	Normal sowing	–0.89	6.78	5.60	–	4.32	8.95
HI 8062 × JNK-4W-128	Normal sowing	–0.66	4.82	13.16	–	3.45	15.19
	Late sowing	–2.97	6.05	18.89	34.45	9.69	52.67
Raj 911 × DWL 5002	Normal sowing	5.04	3.92	8.34	–	7.44	9.86
	Late sowing	6.49	1.49	38.34	47.56	15.61	78.27

First order interactions: [(i) + (j) + (l)]; second order interactions: [(W) + (X) + (Y) + (Z)]; fixable components: [(d) + (i) + (W)]; non-fixable components: [(h) + (j) + (l) + (X) + (Y) + (Z)] (see Table 1).
† See Table 1.

Table 3. Components of heterosis for spike area under normal and late sowing.

Components of heterosis†	Cocorit 71 × A-9-30-1	HI 8062 × JNK-4W-128		Raj 911 × DWL 5002	
	NS‡	NS	LS	NS	LS
(h)	6.78	4.82	6.05	3.92	1.49
–(i)	–3.43	–2.79	–2.09	–2.09	–8.49
½ (X)	–	–	–2.55	–	14.13
¼ (Z)	–	–	1.04	–	–4.45
–(d)	0.89	0.66	2.97	–5.04	–6.49
½ (j)	0.98	0.52	–2.99	2.42	4.97
–(W)	–	–	–4.63	–	–0.63
–¼ (Y)	–	–	5.14	–	–0.22
Heterosis	4.97	3.40	8.00**	–3.42	0.14
Inbreeding depression	9.77**	6.17	2.49	5.81	8.61*

† See Table 1.
‡ NS = normal sowing; LS = late sowing.
*, ** significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.

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Relationship among Diploid Wheats Based on Yield Traits

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Abstract

Information regarding wild genomes/species relationships is vital for deciding on the inclusion of a particular relative in a crossing program for wheat (*Triticum aestivum* L. subsp. *aestivum*). There is also lack of information on the yield traits of the various B, A and D genome species. Seventy-one wild and domesticated diploid wheats were grown under field conditions in a randomized complete block design with three replications. The analysis of means revealed that for straw yield and kernel weight, the tall and large-kernel A genome accessions were significantly superior to the dwarf and small-kernel B genome accessions. For biomass, harvest index and grain yield, the means of B and D genome accessions were significantly greater than the means of A genome accessions. Carbon isotope discrimination value was lowest in one of the B genome species, which is an indicator of high water-use efficiency. Contrast studies showed significant differences among the species and

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العلاقة بين الأقماح الثنائية التضاعف بالاستناد إلى خصائص الغلة

الملخص

تعتبر المعلومات حول العلاقات بين المجموعات الجينية البرية /الأنواع، حيوية لاتخاذ قرار بضم أحد الأقارب إلى أحد برامج التهجين الخاصة بالقمح (*Triticum aestivum* L. subsp. *aestivum*). كما أن هناك نقصاً في المعلومات حول خصائص الغلة لأنواع المجموعات الجينية المتعددة B ، A ، وD . وقد تمت زراعة 71 قمحاً ثنائي التضاعف برياً ومدجناً تحت الظروف الحقلية في تصميم للقطع العشوائية الكاملة بثلاثة مكررات. وقد كشف تحليل المتوسطات أنه بالنسبة لغلة التبن ووزن الحبة، كانت مدخلات المجموعة الجينية A الطويلة والكبيرة الحبة، متفوقة معنوياً على مدخلات المجموعة الجينية B القزمة والصغيرة الحبة . أما بالنسبة للكتلة الحيوية، دليل الحصاد، والغلة الحبية، فقد كانت متوسطات مدخلات المجموعتين الجينيتين B وD أكبر معنوياً من متوسطات مدخلات المجموعة الجينية A . وكانت القيمة التمييزية للكاربون النظير أدنى في نوع واحد من أنواع المجموعة الجينية B، مما يشير إلى كفاءة عالية في استعمال المياه . وبينت دراسات التباين أن هناك فروقاً كبيرة بين الأنواع وبين المجموعات الجينية فيما يتعلق بخصائص الغلة المتعددة. وتدرس حالياً العلاقات بين الأنواع وبين المجموعات الجينية على أساس خصائص الغلة.

between the genomes for various yield traits. Relationships based on yield traits among the species and between the genomes are discussed.

Key words: *Aegilops;* wheats; diploidy; genomes; yield components; straw; grains; yields; kernels; weight; biomass; harvest index; carbon; isotopes; efficiency; USA.

Introduction

Common bread wheat is a hexaploid ($2n$=$6x$=42) with the genome formula BBAADD (Waines and Barnhart 1990). Hirai and Tsunewaki (1981) hypothesized that the B genome donor is one of the species of Sitopsis group (S genome). *Triticum urartu* or *T. monococcum*, and *Aegilops squarrosa* are donors of A and D genomes, respectively (Dvorak 1976; McFadden and Sears 1946).

Higher grain yield potential combined with improved stability of production and better protein quality is the major objective of most wheat breeding programs. Both cultivated and wild species of wheat are being employed in breeding programs to enhance the quality, water-use efficiency and increased pest-resistance capacity.

Information regarding the wild genomes/species relationships is vital for deciding on the inclusion of a particular relative in a crossing program. Based on the migration of protein bands, Waines et al. (1982) concluded that there is a greater homology between *Ae. sharonensis* and *Ae. bicornis* than between *Ae. sharonensis* and *Ae. longissima*. However, Thiellement et al. (1988), based on their two-dimensional electrophoretic patterns, have shown that *Ae. longissima is* more closely related to *Ae. sharonensis*.

Among the A genome species, it has been shown that *T. monococcum* is a domesticated form of *T. boeoticum*, and these two species are related to *T. urartu*, another probable A genome donor. It was evident from the studies of Thiellement et al. (1988) that the D genome donor *Ae. squarrosa* (*Ae. tauchii*) is more closely related to the Sitopsis species than the A genome donor.

There is little information on the yield traits of the various B, A and D genome species. Furthermore, very few studies have compared the different wild species based on yield parameters. Hence, it was intended in this study to focus on the yield traits of all five Sitopsis group species, the three species of the A genome and the D genome species for comparison purposes. The main objectives of this study were to: (1) study the yield parameters of the 71 diploid species, (2) compare all five species of the Sitopsis group, (3) compare the three probable A genome donor species, and (4) compare the S vs A genome.

Material and Methods

The material for the present study consisted of 43 accessions of the S genome (*Ae. speltoides*, *Ae. longissima*, *Ae. searsii*, *Ae. sharonensis* and *Ae. bicornis*). For the A genome, 22 accessions of *Triticum boeoticum*, *T. monococcum* and *T. urartu* were included. The D genome (*Ae. squarrosa*) was represented by six accessions. The origin of the accessions used in the study, the experimental methods and the record of observations have been outlined elsewhere (Rafi 1990; Rafi et al. 1992). The following morphological traits were studied: straw yield/plant, above-ground biomass, harvest index, grain yield/plant, 100-kernel weight and carbon isotope discrimination.

Statistical analyses were done using MSTAT-C statistical software package (MSTAT-C 1990). Analysis of variance was performed on the six traits studied. Single degree of freedom orthogonal contrasts were made as follows:

In the S genome:

i) As per the dendrogram of Thiellement et al. (1988), a distantly placed *Ae. speltoides* was compared with the other four species.
ii) *Aegilops longissima* was compared against *Ae. searsii*.
iii) According to Waines and Johnson (1972), *Ae. sharonensis* was contrasted against the morphologically similar *Ae. bicornis*.
iv) *Aegilops longissima* and *Ae. searsii* were combined together and contrasted against *Ae. sharonensis* and *Ae. bicornis* in combination.

In addition, the following comparisons were made:

i) *Aegilops longissima* was compared against *Ae. sharonensis*, and
ii) *Aegilops searsii* was contrasted against *Ae. bicornis*.

In the A genome:

i) *Triticum boeoticum*, a wild diploid, was compared with its domesticated form, *T. monococcum*.
ii) Closely related *T. boeoticum* and *T. monococcum* were pooled and compared with their distant relative, *T. urartu*.

Also, the S genome was compared against the A genome.

Results and Discussion

The means of the different genomes and species for straw yield/plant, above-ground biomass, harvest index, grain yield/plant, 100-kernel weight and carbon isotope discrimination ($\delta\ ^{13}C$) are summarized in Table 1. Among diploids, the A genome accession had significantly higher mean straw yield compared to the Sitopsis group. Among the nine species of diploids, *Triticum monococcum* (56.03 g) ranked first followed by *Aegilops speltoides* (43.90 g). The least straw and biomass were produced by *Ae. bicornis* (17.32 g and 39.19 g, respectively). Biomass production of *Ae. squarrosa* was significantly greater than that of the Sitopsis group and the A genome accessions.

Among the three diploid genomes, harvest index and grain yield were significantly higher in the B and D genomes than in the A genome. However, considering the individual species, *Ae. bicornis* had the greatest harvest index (56.09%). For 100-kernel weight, means of A and D genomes were significantly greater than that of the Sitopsis group. *Triticum monococcum* had the highest (1.47 g) and *Ae. bicornis* (0.47 g) the lowest mean 100-kernel weight values. The lowest mean value for $\delta\ ^{13}C$, which is indicative of increased water-use efficiency (Ehdaie et al. 1991), was observed for *Ae. sharonensis* (17.27×10^3) followed by *T. monococcum* (17.44×10^3).

Comparisons between means of various yield components of the B and A genomes are shown in Table 2. Mean differences between *Ae. speltoides* and the other four B genome species were highly significant for straw yield, harvest index, grain yield and $\delta\ ^{13}C$. This is not unexpected since *Ae. speltoides* is considered distant from the other four species (Kimber and Feldman 1987; Thiellement et al. 1988). Mean differences of morphologically similar-looking species, *Ae. longissima* and *Ae. searsii*, and *Ae. sharonensis* and *Ae. bicornis* were non-significant for grain yield and 100-kernel weight, and grain yield and $\delta\ ^{13}C$, respectively, for the pairs. Because of the taller plant type of *Ae. longissima* over *Ae. searsii*, and *Ae. sharonensis* over *Ae. bicornis*, significant differences were observed for straw yield, biomass and harvest index. If the hypothesis of Thiellement et al. (1988) is true, that *Ae. longissima* is more closely related to *Ae. sharonensis*, then, less significant differences would be expected between these two species. On the contrary, for genetically induced traits such as grain yield and 100-kernel weight, significant differences were obtained. However, these results are consistent with the findings of Waines and Johnson (1972) and Waines et al. (1982), who suggested that there is greater homology between *Ae. sharonensis* and *Ae. bicornis* than between *Ae. sharonensis* and *Ae. longissima*.

In the A genome, a comparison between *T. boeoticum* and *T. monococcum* showed significant differences in mean values for all the traits except harvest index. Increased mean values for various traits in *T. monococcum* could be explained by the process of domestication. When the coefficients of *T. boeoticum* and *T. monococcum*—the two closely related species—were combined and compared against their relative, *T. urartu*, the differences in mean values were highly significant for all traits, indicating a distant relationship between the former two species with the latter.

Contrasts made between the S and A genomes revealed highly significant differences in the mean values for all the traits except biomass. Increased biomass value in the S genome could be due to increased head yield (data not

Table 1. Means of yield traits of the three genomes and eight species of *Aegilops* and *Triticum*.

Genome/species	No. of accessions	Straw yield (g)	Biomass (g)	Harvest index† (%)	Grain yield (g)	100-kernel weight (g)	$\delta\ ^{13}C$ ($\times 10^3$)
B	43	29.32	53.28	45.90	9.55	0.61	17.89
A	22	42.21	56.36	25.86	4.57	1.10	18.17
D	6	39.68	76.17	47.55	14.54	1.06	17.62
Ae. speltoides	8	43.90	66.49	33.61	7.14	0.63	18.48
Ae. longissima	8	32.90	59.43	44.19	9.52	0.59	17.59
Ae. searsii	11	27.10	52.22	47.74	8.67	0.58	17.55
Ae. sharonensis	6	29.19	52.88	44.24	11.51	0.87	17.27
Ae. bicornis	10	17.32	39.19	56.09	11.71	0.48	18.42
T. boeoticum	8	39.25	51.46	22.83	3.16	0.89	18.55
T. monococcum	7	56.03	72.95	24.41	6.30	1.47	17.44
T. urartu	7	31.79	45.39	30.78	4.45	0.97	18.47

† Ratio of head yield to biomass yield.

Table 2. Orthogonal contrasts among species of *Aegilops* and *Triticum* for different yield traits.

Contrasts (g)	Straw yield (g)	Biomass (g)	Harvest index (%)	Grain yield (g)	100-kernel weight (g)	$\delta^{13}C$ (× 10^3)
Ae. speltoides vs other B genome species	** (43.90–26.63)	(66.49–50.93)	** (33.61–48.07)	** (7.14–10.53)	(0.63–0.63)	** (18.48–17.71)
Ae. longissima vs *Ae. searsii*	** (32.90–27.10)	* (59.43–52.22)	** (44.19–47.74)	(9.52–8.67)	(0.59–0.58)	(17.59–17.55)
Ae. sharonensis vs *Ae. bicornis*	** (29.19–17.32)	** (52.88–39.19)	** (44.24–56.09)	(11.51–11.71)	** (0.87–0.48)	** (17.27–18.42)
Ae. longissima vs *Ae. sharonensis*	(32.90–29.19)	(59.43–52.88)	(44.19–44.24)	* (9.52–11.51)	** (0.59–0.87)	* (17.59–17.27)
Ae. searsii vs *Ae. bicornis*	** (27.10–17.32)	** (52.22–39.19)	** (47.74–56.09)	** (8.67–11.71)	** (0.58–0.48)	** (17.55–18.42)
Ae. longissima + *Ae. searsii* vs *Ae. sharonensis* + *Ae. bicornis*	** (30.00–23.26)	** (55.83–46.04)	** (45.97–50.17)	** (9.10–11.61)	(0.59–0.68)	** (17.57–17.85)
T. boeoticum vs *T. monococcum*	** (39.25–56.03)	** (51.46–72.95)	(22.83–24.41)	** (3.16–6.30)	** (0.89–1.47)	** (18.55–17.44)
T. boeoticum + *T. monococcum* vs *T. urartu*	** (47.64–31.79)	** (62.21–43.39)	** (23.62–30.78)	* (4.73–4.45)	** (1.18–0.97)	** (18.00–18.47)
S vs A genome	** (29.32–42.21)	(53.28–56.36)	** (45.90–25.86)	** (9.65–4.57)	** (0.61–1.10)	** (17.89–18.17)

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

shown), and in the A genome it could be due to increased straw yield. Highly significant differences between these two genomes are expected since these two belong to different genera and they are only distantly related.

In conclusion, this study has generated information regarding the yield traits and relationship of the less-studied diploid wild and domesticated relatives of bread wheat. This information could be effectively used for inclusion of a relative in a cross-breeding program for enhancing any particular trait in hexaploid wheat.

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Contribution of the Bc Institute in Zagreb in Breeding and Seed Production of Winter Wheat in the Republic of Croatia†

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Abstract

The work on breeding of winter wheat (*Triticum aestivum* L. subsp. *aestivum*) at Zagreb Bc Institute was initiated as early as 1947 under the guidance of Dr. Josip Potočanac. After a certain time and acquired knowledge in wheat breeding and production under Croatia's conditions, Dr. Potočanac developed a model of Bc wheats, which is based on an increased plant density, after the model of Italian wheat cultivars combining their traits with those of American cultivars. With certain changes, this model was accepted by the breeders from the Bc Institute, and in 1971 the cultivars Zlatna Dolina and Sanja were released. Zlatna Dolina was 15% more yielding in wide production than the leading Italian cultivar Libellula. Later, 55 high-yielding wheat cultivars developed by the Bc Institute were registered and accepted for production both at home and abroad. From 1975 to 1985, Bc cultivars of winter wheat dominated in Croatia's production. They accounted for more than 70% of the acreage under wheat. Today, their share has stabilized at around 50%. Under conditions of intensive production, Bc cultivars achieve yields above 10 t/ha. From 1975 on, remarkable quantities of seeds have been produced from Bc cultivars, not only to satisfy the nation's needs but also for export. Seed production was especially successful in the period from 1982 to 1985. Following the basic wheat model, marked improvements of the relevant traits have been achieved in the new varieties and lines.

Key words: *Triticum*; winter crops; selection criteria; varieties; spacing; seed production; Croatia.

مساهمة معهد Bc في زغرب في تربية وإنتاج قمح شتوي في جمهورية كرواتيا

الملخص

يرجع العمل في تربية القمح الشتوي (.*Triticum aestivum* L subsp. *aestivum*) في معهد Bc في زغرب إلى عام 1947 وبإشراف الدكتور جوزيب بوتوجاناك. وبعد مرور فترة محددة من الزمن واكتساب الخبرة بتربية القمح وإنتاجه تحت الظروف الكرواتية، قام الدكتور بوتوجاناك بوضع نموذج لأقماح Bc على أساس تزايد الكثافة النباتية، على غرار نموذج أصناف القمح الإيطالية الذي يوّحد بين خصائص تلك الأصناف وخصائص الأصناف الأمريكية. وقد وافق مربو معهد Bc على هذا النموذج بعد إدخال بعض التغييرات عليه، وتم اعتماد الصنفين زلاتنا دولينا وسانجا في 1971. وقد تفوق زلاتنا دولينا في الغلة على أحسن صنف إيطالي، ليبليولا بنسبة 15%. وفيما بعد ، تم تسجيل وقبول 55 صنفاً مغلالاً من القمح استنبطت من قبل معهد Bc، للإنتاج داخل البلد وخارجه على السواء. وخلال الفترة الواقعة بين 1975 و 1985، كانت أصناف Bc من القمح الشتوي سائدة في الإنتاج الكرواتي، إذ بلغت المساحات المزروعة بها ما يزيد على 70% من المساحات المزروعة بالقمح. وفي الوقت الحاضر، استقرت حصتها من الإنتاج عند حدود 50%. وتعطي أصناف Bc تحت ظروف الإنتاج المكثف غلة تتجاوز 10 طن/هـ. ومنذ عام 1975، تم إنتاج كميات كبيرة من بذور أصناف Bc، ليس بغرض تلبية الطلب المحلي فحسب بل ولتلبية احتياجات التصدير. وكان إنتاج البذور ناجحا على نحو خاص خلال السنوات الواقعة بين 1982 و 1985. وقد تم في أعقاب وضع نموذج أساسي للقمح تحقيق تحسينات ملحوظة في خصائص الأصناف والسلالات الجديدة.

Introduction

Breeding and genetic work on developing new winter wheat cultivars at the Bc Institute for Breeding and Production of Field Crops in Zagreb constitutes part of the program for advancing wheat production in Croatia. To date, 55 winter wheat cultivars have been developed, which are suited to different agroecological growing conditions. Many of these cultivars have been accepted by wheat growers both at home and abroad; eight cultivars have been registered so far (in Italy, Hungary, Czech Republic, Slovak Republic and Bulgaria). Owing to their positive traits (high-yielding potential and yield stability because of their genetic resistance to fungal diseases) and adaptability to local growing conditions, winter wheat Bc cultivars represent the leading seed material in the country.

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According to the nation's program for advancement of wheat production, one of the basic tasks of the Bc Institute is to provide sufficient quantities of high-quality seed (super elite and elite) to satisfy the nation's needs and for export. There is coordinated cooperation in the production of wheat seeds between the Institute and the producers who are adequately equipped for modern production of the seeds (Tomasović 1985).

Breeding of winter wheat is a very complex task. At the Bc Institute, it is done within several programs the basic objective of which is the development of semi-dwarf and moderately tall cultivars with increased productivity, wide adaptability and improved kernel and flour quality. The basic concept of wheat breeding (the model of Bc cultivars) was set by Dr. Josip Potočanac as early as 1966, in which yield was based primarily on optimal plant density, and yield stability on resistance to the most important wheat diseases (Potočanac 1984; Javor 1984). This model was closely followed yet with considerable modifications and supplements. Along with the basic objectives—to maintain high yield stability by breeding for resistance to the most important diseases and to improve kernel and flour quality—further intensive improvements of relevant properties are being pursued within several programs under the guidance of wheat breeders at the Institute who set an objective to achieve yields of 15 t/ha because, already in 1983 and 1984, yields of 10 t/ha and more were produced in nationwide production.

Breeding and Seed Production of Winter Wheat at the Bc Institute in Zagreb

The Bc Institute possesses a large gene pool, which is growing year after year, of different genetic materials with various wheat properties. These materials undergo preliminary investigations, and selection is made to find genotypes for breeding which would presumably broaden the genetic variability of the existing material. The breeding process is closely linked with phytopathological investigations of the economically most important wheat diseases. Testing of yield and adaptability of the new materials is performed in field trials at several locations. The most promising lines are then tested in production experiments in large areas.

Production of the basic seed is performed by maintaining elite seeds through multiple selection of the best progenies of selected spikes within a cultivar's population. These are harvested in bulk provided that off-types of a progeny are discarded before the progenies of spikes are increased, i.e., those that do not satisfy the required criteria (negative selection–screening). The planted progenies of spikes are monitored through the entire vegetation.

Discussion

Breeding winter wheat at the Bc Institute in Zagreb

With continuous improvement of the Institute's breeding work, new cultivars have been developed. They possess high genetic yielding potential and are suited to different agroecological growing conditions, which has marked significance on their spreading both at home and in neighboring countries. The new Bc cultivars of winter wheat are increasingly grown throughout the country and are regaining a significant share in the nation's production (about 50% according to the latest reports). Among them, Sana and Marija are especially distinguished and one might say that they have made their mark in the nation's production. Owing to their high yielding capacity and the results achieved in agricultural production both at home and abroad, the above cultivars serve as standards for the committees for registration of new wheat cultivars (Sana, the standard for the Committee of the Republic of Croatia, and in Hungary under the name Corona; Marija, the standard for the Committee of the Republic of Slovenia). Because of their high yield and improved kernel and flour quality, both Sana and Marija satisfy strict criteria of the market.

Next to Marija and Sana, a prominent place is taken by Alena, Adriana and a new cultivar, Ida, which represents excellent raw material for the confectionery industry (sedimentation value = 7–10 ml). Bc cultivars from the latest cycle of breeding that are entering production are Darka, Rina, Melita, Davorka, Sandra, Sutla, Tina, Rugvica and Olga (Table 1). In normal years and when planted on the optimal date (10–25 October), they produce yield well above 8 t/ha of dry grain, while their yielding potential is much higher, more than 10 t/ha. This also applies to the latest lines that are in the process of registration in Croatia and some other countries. Some of them are presented in Table 2. Considerable progress has been made in the latest Bc varieties and lines in terms of kernel and flour quality. Higher levels of protein content and sedimentation value have also been achieved, by which some cultivars or lines belong most often to quality class I and some to class II (Table 3).

New cultivars and lines exhibit good farinological properties, of which water absorption should be emphasized. Extensograph values are also relatively good. As for indices of seed quality, the increase in 1000-kernel weight compared to cultivars from earlier breeding programs is highly

Table 1. Grain yield and relevant agronomic traits of some new winter wheat cultivars developed by the Bc Institute in Zagreb in small-scale trials, 1991–93.

Cutivar	Grain yield			1000-kernel weight (g)	Test weight (kg)	Plant height (cm)	Lodging (%)	Vegetation length (± days from Sana)	Disease attack			
	Cultivar (kg/ha)	Sana (kg/ha)	Relative to Sana (Sana = 100%)						Powdery mildew (0–9)	Leaf rust (Cobb's scale)	*Septoria* spp. (0–9)	*Fusarium* spp. (0–5)
Darka	8858	8892	99.62	47.0	77.2	73	0	−1	1–2	OR	2	0
Davorka	9202	9168	100.37	45.0	78.0	77	0	−2	3	OR	0	1
Melita	8862	8892	99.66	42.0	77.0	77	0	−1	1	OR	0	0
Olga	8000	7600	105.26	49.5	78.9	82	2–3	+2	3–4	OR	2–3	0
Rina	9740	8892	109.53	43.5	76.0	75	0	−1	0–1	OR	1	0
Rugvica	9850	9152	107.62	46.5	78.5	79	0	+3	4	TR	2	0
Sandra	8232	7878	104.49	47.0	78.4	84	5	+2	3–4	OR	3	0
Sutla	9236	9152	100.91	43.5	77.8	80	4	+4	4–5	OR	2–3	0
Tina	8124	8290	97.99	46.5	75.5	72	0	0	2	TR	2	0
Ida	8836	8444	104.64	47.5	77.0	80	0	0	1	OR	0	0

Table 2. Grain yield and relevant agronomic traits of some new winter wheat lines developed by the Bc institute in Zagreb in small-scale trials, 1991–93.

Cutivar	Grain yield			1000-kernel weight (g)	Test weight (kg)	Plant height (cm)	Lodging (%)	Vegetation length (± days from Sana)	Sedimentation value (ml)	Disease attack			
	Line (kg/ha)	Sana (kg/ha)	Relative to Sana (Sana = 100%)							Powdery mildew (0–9)	Leaf rust (Cobb's scale)	*Septoria* spp. (0–9)	*Fusarium* spp. (0–5)
ZG 4160/91	10720	10004	107.15	44.0–51.5	78.0	80	0	0	24	1–2	OR	0	1
ZG 4166/91	10460	10004	104.56	40.0–46.0	78.4	77	0	0	37	1–2	OR	0	1
ZG 3037/91	10244	10004	102.12	44.0	78.2	78	0	0	36	2	OR	0	1
ZG 100/91	8236	7792	105.70	41.7–47.5	75.4	75–77	0	-2	35–43	2–3	OR	0	0
ZG 18/91	7800	7688	101.46	42.0–43.5	76.0	73–76	0	0	35–50	0–1	OR–TR	0–1	0–1
ZG 31/91	8548	8068	105.95	40.2–48.5	74.8	67–72	0	+2	36–42	0	25 MS	0–1	0–1
ZG 3311/92	9624	9448	101.86	45.0–52.5	76.8	82–88	5	-2	35–40	2–3	OR–TR	0–1	0–1

Table 3. Quality indices of some new winter wheat cultivars developed by the Bc Institute.

Cultivar	Protein (%)	Sedimentation value (ml)	Quality class	Farinograph			Extensograph		
				Water absorption	Quality number	Quality group	Extensib. (mm)	Resistance (EJ)	Ratio (O/R)
Darka	12.9	34.7	II	57.0	58.5	B1	166	230	1.38
Davorka	13.3	30.8	II	50.8	53.9	B2	187	355	1.89
Melita	12.4	33.8	II	55.5	55.1	B1	171	190	1.11
Olga	11.5	43.0	I–II	59.3	65.0	B1	147	245	1.32
Rina	12.0	38.0	II	50.0	35.4	C1	116	340	2.93
Rugvica	11.6	22.9	III	52.0	50.6	B2	116	340	2.93
Sandra	14.0	47.8	I	57.7	67.3	B1	139	215	1.54
Sutla	12.2	31.8	II	62.0	47.4	B2	129	470	3.64
Tina	13.8	64.4	I	53.8	63.8	B1	180	320	1.78

pronounced, where the weight reaches 40–45 g or more, and in some materials, even 50 g or more. The old cultivar Zlatna Dolina had an average 1000-kernel weight of 30–35 g. Tables 1 and 3 show that the new cultivars and lines have high levels of resistance to the most important fungal diseases affecting wheat (black stem rust, powdery mildew, *Septoria* spp. and *Fusarium* spp.). They have moderately tall stem of good strength and exhibit very good resistance to lodging. Regarding maturity, they belong to mid to early types.

A remarkable contribution to higher yield per spike was made with the discovery of genes that control branching (Ramicra), furrowing (Tetrastichon) and normal spike form of *Triticum aestivum* L. wheat (Rm, Ts and Nr genes). In our breeding work, branching genes are frequently used for developing highly productive normal genotypes, which basically influences the change in spike structure. Production of 103 kernels/spike was achieved in lower population densities. This size also results in higher 1000-kernel weight and an increased number of kernels per spikelet (3–5); hence, an increased number of kernels per spike. Certainly, efforts are still being made to reduce stem height and to improve its quality by incorporating resistance to lodging in genotypes with long spikes. Such materials are already planted in our fields and are increasingly entering wide production.

In the breeding program aimed at raising yield capacity, efforts are being made to maintain the density common for the well-known Bc cultivars, Baranjka and Super Zlatna, and to increase the number of spikelets in a spike, which at the same time means achieving an increased number of kernels per spike. Efforts are being made in parallel to increase 1000-kernel weight. The new lines have more than 20 fertile spikelets, some even 27. Among the genotypes developed on the basis of higher production per spike, there are some with 33 spikelets in a spike (data on such a large number of spikelets have not been found in the literature). It is known that the famous cultivar Zlatna Dolina had about 16 spikelets with a 1000-kernel weight of about 35 g.

Importance of the Bc cultivars in seed production of winter wheat in the Republic of Croatia

During the last 30 years, great progress has been made in Croatia's wheat breeding, which has resulted in a permanent yield increase per unit area. A marked contribution was made by the Bc Institute with its newly developed cultivars. Owing to their positive traits and adaptability to local growing conditions, they have had a marked share in acreage under wheat. There, where science and production were most closely linked, grain yields were achieved that rank among the highest in the world, because the advancement in production technology allows wheat cultivars to express their yielding potential to a great extent. The result of the efforts is a considerable growth of yield per unit area in the country. Development of new cultivars, seed production and advanced production technology come as a result of numerous scientific investigations, which together contribute to higher profitability of wheat production. Thus, on socially owned farms in Croatia, the average grain yield achieved reached 6.9 t/ha.

According to the nation's program for advancing wheat production, the prime task of the Bc Institute is to provide sufficient quantities of quality seed (super elite and elite), both for home and the foreign market. This long-term program requires cooperation between the Bc Institute and well-equipped farm producers for organized seed production throughout the country. Table 4 presents the data on seed production of wheat in the Republic of Croatia and the share of the Bc Institute in total seed production for the period from 1983 to 1994. The highest amount of seed was produced in 1987, and from 1983 to 1986, Bc wheat cultivars predominated in harvested acreage under wheat in Croatia. After this period, a slight decline occurred and, at present, the share of Bc cultivars has stabilized at around 50%.

The aim of this work was to demonstrate the production and marketing of Bc cultivars in the Republic of Croatia during 1991–94, when notable sales of wheat seed were achieved despite unfavorable conditions in the country. A continuous growth of marketed seeds of Bc wheat cultivars was noticed in 1991–94, which meant a significant contribution of the Bc Institute to the nation's seed production.

Table 4. Seed production of winter wheat in the Republic of Croatia and the share of the Bc Institute in the total seed production for the period from 1983 to 1994†.

Year	Production (t)	Share (%)
1983	37,262	95
1984	30,582	93
1985	32,068	96
1986	34,747	76
1987	57,372	60
1988	34,090	61
1989	29,186	59
1990	41,734	53
1991	11,841	–
1992	14,552	–
1993	18,199	–
1994	18,077	–

† Data from the Bc Institute's sales department.

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Zagros: A New Bread-Wheat Cultivar Released in Iran

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Abstract

Research is conducted to develop and release new improved spring-wheat (*Triticum aestivum* L. subsp. *aestivum*) cultivars which can better tolerate the stresses affecting wheat, particularly in the rainfed areas of Iran. A research strategy based on the collection of local germplasm and importing genetically diverse exotic material to expand the genetic base of wheat breeding was developed and followed during the last 10 years. In the 1989/90 crop season, 142 lines received from CIMMYT were evaluated. On the basis of agronomic score and yellow-rust resistance under field conditions, a line, Tan'S'/Vee'S'//Opata, was selected. It was further evaluated at major research centers in the warm areas of Iran together with another 18 lines, including the widely grown improved check cultivar Maroon. Results revealed that this new line is similar in all agronomic traits to Maroon, but is much more tolerant to yellow rust and gives significantly higher and stable yield. Based on these evaluations, this new line was released under the name Zagros.

Key words: *Triticum aestivum*; soft wheat; spring crops; introduced varieties; disease resistance; rusts; *Puccinia striiformis*; yields; Iran.

زاغروس : صنف جديد من القمح الطري في إيران

الملخص

تُجرى الأبحاث لاستنباط واعتماد أصناف جديدة محسنة من القمح الربيعي تتحمل على نحو أفضل الإجهادات التي تؤثر في القمح (*Triticum aestivum* L. subsp. *aestivum*)، لاسيما في المناطق البعلية من إيران. وخلال السنوات العشر الماضية ، تم وضع واتباع استراتيجية للبحوث قائمة على جمع الأصول الوراثية المحلية ، واستقدام مواد مُدخلة متنوعة وراثيا بغية توسيع القاعدة الوراثية لتربية القمح . وفي الموسم الزراعي 1989/90، قُيمت 142 سلالة مُرسلة من سيميت . وقد انتُخِبت السلالة Tan 'S'/Vee'S'//Opata على أساس الخصائص الزراعية ومقاومة الصدأ الأصفر تحت الظروف الحقلية ، ثم أُجريَ عليها مزيد من التقييم في مراكز االبحوث الزراعية الرئيسية في المناطق الدافئة من إيران، مع 18 سلالة أُخرى بما فيها صنف الشاهد المحسن مارون الذي يزرع على نطاق واسع. وبينت النتائج ان هذه السلالة الجديدة مشابهة في جميع خصائصها الزراعية لمارون إلا أنها أكثر احتمالا للصدأ الاصفر وتعطي غلة أكبر معنويا وأكثر استقرارا. وانطلاقا من هذه التقييمات ، تم اعتماد هذه السلالة الجديدة تحت اسم زاغروس .

Introduction

Wheat occupies a pivotal position in Iranian agriculture and is cultivated in over 6 million hectares (Anonymous 1995) under very diverse agroclimatic conditions. Though wheat cultivars with various growth habits are cultivated in various parts of the country, the predominant cultivars are of winter, spring or facultative type. Spring wheats are grown both under rainfed and irrigated conditions in relatively warm areas where the temperatures rarely fall below freezing during the crop-growth cycle.

Iran made major strides in the development of wheat cultivars for irrigated areas, but the progress in the development of cultivars for rainfed areas has been relatively slow due to serious environmental (drought and high temperature) and biotic (diseases, especially yellow rust) stresses. Drought results not only from inadequate rainfall but also from erratic rainfall distribution, which causes stress at various crop-development stages. Besides drought, the other major problem which has become very serious with the intensification of agriculture during the past years is yellow rust (*Puccinia striiformis*). Yellow rust appeared in epidemic form during the 1992/93 and 1993/94 crop seasons, primarily in the spring-wheat growing areas of Iran. To overcome these problems, research efforts were intensified to develop and release new improved spring-wheat cultivars which can better tolerate the prevailing stresses. The research strategy and results on the development and release of a new cultivar, Zagros, are reported here.

Material and Methods

To combat the various stresses affecting wheat, a research strategy based on the collection of local germplasm and importing genetically diverse exotic material to expand the genetic base of wheat breeding was developed and followed during the last 10 years. A large amount of breeding material from national and international sources is evaluated at several locations each year to identify suitable high-yielding, yellow-rust-resistant varieties. In the 1989/90 crop season, 142 lines were received from CIMMYT in the form of the 8th Wheat Screening Nursery for Semiarid Areas. On the basis of agronomic score and yellow-rust resistance under field conditions, a line, Tan'S'/Vee'S'//Opata (CM 82781-030 TOPM-14Y-25H-05H-05Y-05RB-OH), was selected. This line was included in the Preliminary Yield Trials for evaluation at Gachsaran and Khoramabad (Amiri et al. 1994, 1995) and was tested simultaneously at Karaj, Moghan and Gorgan. On the basis of good performance, it was included in the National Uniform Wheat Yield Trials for evaluation and testing along with another 18 lines, including the widely grown improved check cultivar Maroon, at all the major research centers in the warm areas of Iran using a randomized complete block design with three replications.

Data on plant height, number of tillers/plant, lodging, days to maturity, 1000-kernel weight and yield were recorded. Data on all the three wheat rusts were also recorded under field and artificial inoculation conditions. Detailed results on the performance of all the tested lines in these multilocational trials throughout the spring-wheat growing areas are summarized in the Annual Report of the Dryland Agricultural Research Institute (Amiri et al. 1996). Mean results of the evaluations at the major research stations of the line Tan'S'/Vee'S'//Opata, which has been released under the name Zagros, along with the check cultivar Maroon are presented and discussed in this paper.

Results and Discussion

Results on the mean agronomic characteristics of the newly released cultivar Zagros and the widely cultivated check variety Maroon are given in Table 1. The lack of significant differences at all locations in plant height of Zagros and Maroon indicated similarity between the two cultivars. At all four testing sites (Gachsaran, Moghan, Kohdasht and Gorgan), Zagros had significantly higher 1000-kernel weight than Maroon (35–42 g for Zagros compared to 30–39.5 g for Maroon). The high 1000-kernel weight is not only an important yield component, but is also a highly desirable trait; farmers readily adopt varieties with bigger and bold grain.

Table 1 indicates that stem rust is not important, as it was not observed on either variety. On the other hand, both varieties had a resistant reaction to leaf rust. Major differences were observed in yellow rust development at all the testing sites. Zagros had no yellow rust development symp-

Table 1. Mean agronomic characteristics of cultivar Zagros at different research stations, 1995/96.

Station	Plant height (cm)	Tillers/ plant	Lodging†	Maturity (days)	Rust Yellow	Rust Leaf	Rust Stem	1000-kernel wt (g)	Yield (kg/ha)
Gachsaran	96.3	3–4	R	136	0	5MR	–	35	3697
	(97.0)‡	(3–4)	(R)	(139)	(40S)	(–)	(–)	(30)	(3211)
CV (%)									11.62
LSD (5%)									336
Moghan	81.5	NA	R	209	10MS	10R	–	39.7	5150
	(81.0)	NA	(R)	(210)	(50S)	(20MR)	(–)	(34.0)	(4600)
CV (%)									13.53
LSD (1%)									299
Kohdasht	89.3	NA	R	179	5MR	–	–	42.0	4108
	(81.0)	NA	(R)	(179)	(50S)	(20S)	(–)	(39.5)	(3633)
CV (%)									7.07
LSD (1%)									450
Gorgan	97.5	NA	R	164	10S	–	–	41.8	5242
	(98.5)	NA	(R)	(164)	(80S)	(–)	(–)	(34.5)	(2936)
CV (%)									13.13
LSD (1%)									777

† R = resistant.
‡ Figures in parentheses are for the check cultivar Maroon.
NA = not available; – = not observed.

toms at Gachsaran and only 5MR at Kohdasht in comparison to 40S and 50S, respectively, for Maroon. At high yellow-rust-incidence sites (Moghan and Gorgan), Zagros developed very low levels of infection (10MS and 10S, respectively) in comparison to over 50S and 80S, respectively, for Maroon. These results indicate that the newly released cultivar is highly tolerant or resistant to yellow rust compared to the widely cultivated variety Maroon.

Results on yield revealed that at all locations except Gachsaran, the new cultivar Zagros significantly outyielded the check Maroon. Even at Gachsaran, Zagros yielded 3697 kg/ha compared to 3211 kg/ha for Maroon. At the high-yielding site Gorgan, Zagros gave a yield of 5242 kg/ha compared to 2936 kg/ha for Maroon. This large difference in yield is most likely due to heavy infestation with yellow rust (80S) on Maroon, which adversely affected 1000-kernel weight and yield.

It can thus be concluded that the new line Tan'S'/Vee'S'//Opata is similar in all agronomic traits to the widely cultivated variety Maroon, but is much more tolerant to yellow rust and gives significantly higher and stable yield. Based on these evaluations, the National Variety Release Committee recommended the release of this new line under the name Zagros—a mountain in Iran for general cultivation in the dry areas of the country.

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Characteristics of New Spring-Wheat Cultivars Released in Iran

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Abstract

The predominant wheat (*Triticum aestivum* L. subsp. *aestivum*) variety cultivated by farmers in Iran is Maroon, which is high yielding and widely adapted. The large-scale cultivation of a single genotype has placed wheat production at high risk. This became evident in 1993/94 and 1994/95 with the breakdown of Maroon under new races of yellow rust, which resulted in the acceleration of wheat-breeding efforts to release more cultivars with diverse genetic make-up to overcome the yellow-rust problem. In addition to a new wheat cultivar, Zagros, released earlier, two improved wheat varieties, Niknegad and Gaher, were released for cool and

صفات أصناف جديدة من القمح الربيعي في إيران

الملخص

يعتبر مارون الصنف السائد من القمح (*Triticum aestivum* L. subsp. *aestivum*) الذي يُزرع من قبل المزارعين في إيران، وهو صنف مغلال وواسع التكيف. إلا أن زراعة طراز وراثي واحد على نطاق واسع قد عرّض إنتاج القمح إلى خطر محدق. وقد اتضح ذلك في موسمي 94/1993 و95/1994 عندما هلك مارون تحت وطأة إصابته بسلالات جديدة من الصدأ الاصفر، الأمر الذي أسفر عن تسارع الجهود المتعلقة بتربية القمح بغية اعتماد المزيد من الأصناف ذات التركيب الوراثي المتنوع للتغلب على مشكلة الإصابة بالصدأ الأصفر. وبالإضافة إلى زاغروس، وهو صنف جديد من القمح تم اعتماده في وقت سابق، تم اعتماد صنفين محسنين من القمح هما، نيكنجاد وقاهر، لزراعتهما في المناطق المعتدلة الحرارة ذات الأمطار المتوسطة. وتلخص هذه الورقة متوسط الصفات الزراعية لهذين الصنفين المعتمدين حديثاً .

medium-warm areas with moderate rainfall for general cultivation. The mean agronomic characteristics of these two newly released cultivars are summarized in this paper.

Key words: *Triticum aestivum;* agronomic characters; introduced varieties; disease resistance; *Puccinia striiformis*; Iran.

Introduction

Among the most widely cultivated crops in Iran—in terms of area and production—wheat ranks the highest. Wheat is a staple food for the Iranian people, therefore, it is grown on 6.6 million hectares (Anonymous 1995) in different agroecological regions to meet the ever-increasing domestic requirements.

Although all kinds of wheat are grown, spring bread wheat occupies a significant portion of the cultivated area under rainfed and irrigated conditions in the warm regions of Iran. In spite of the vast area under wheat, the number of wheat varieties cultivated by farmers has been very small, and the predominant cultivar is Maroon, a high-yielding and widely adapted variety. The large-scale cultivation of a single genotype has placed wheat production at high risk. This became evident in the 1993/94 and 1994/95 crop seasons with the breakdown of Maroon under new races of yellow rust (*Puccinia striiformis*), when the production of wheat plunged significantly, compelling the government to import large quantities of wheat grain to meet domestic needs. However, these yellow rust epidemics forced wheat scientists to accelerate their varietal improvement and release process and to diversify varietal complexion by releasing more cultivars with diverse genetic make-up to overcome the yellow-rust problem.

These accelerated wheat-breeding efforts started paying off in the form of the release of new varieties in quick succession. Earlier, a new wheat cultivar, Zagros, had been released (Amiri et al. 1998). However, due to the vast area under wheat cultivation, a large number of new wheat varieties with different genetic backgrounds and carrying different sources of resistance against yellow rust were needed. In view of this, two improved wheat varieties, Niknegad and Gaher, were released for cool and medium-warm areas with moderate rainfall for general cultivation. The characteristics of these newly released improved cultivars are described in this paper.

Material and Methods

In 1988/89, three sets of the Wheat Observation Nursery for Moderate Rainfall Areas were obtained from the International Center for Agricultural Research in the Dry Areas (ICARDA). These sets were planted at Gachsaran, Karaj and Moghan in an unreplicated trial as an observation nursery in two rows, each 2.5 m long. From this nursery, one line, Nd/Vg 9144//Kal/Bb/3/Yaco'S'/4/Vee'S' (later named Gaher), was selected on the basis of yellow-rust resistance and other desirable agronomic traits for further evaluation in preliminary yield trials. This line performed well and was among the top-yielding lines in these trials. On the basis of stable and high yield, it was included in the multilocation National Uniform Wheat Yield Trials for intensive and extensive testing and evaluation to determine its possible release to farmers as Gaher.

The newly released cultivar Niknegad was received as a breeding line, F134-71/Crow'S' (SWM 111-41AP-2AP-4AP-1AP-OAP), developed from a cross made at CIMMYT involving a high-yielding, rust-resistant Romanian winter wheat line, F134-71, and a spring wheat line, Crow'S', from ICARDA in 1989/90 through its international nurseries for evaluation and testing. After extensive testing in preliminary yield trials for evaluation at Karaj, Lorestan, Gachsaran and Moghan, this line was further found to be one of the top yielders in the regional trials. Based on these evaluations, Niknegad was included in the National Uniform Trials along with 18 other lines, including the improved check Maroon, for testing in cool and moderately high-rainfall areas.

Results and Discussion

The improved cultivar Gaher

Plant height of Gaher and the check Maroon ranged from 75 to 90 cm and 83 to 97 cm, respectively (Table 1). On the average, Gaher was shorter (84 cm) than Maroon (90 cm). Both cultivars are resistant to lodging. The new cultivar is medium in maturity while Maroon is slightly earlier. However, this slightly late maturity does not seem to have adverse effects on productivity due to terminal drought.

Gaher is resistant to moderately resistant to yellow rust, with a maximum infection of 10MR at most of the test locations. Only at Gorgan, an infection of 5S under heavy epiphytotic conditions was observed. The widely cultivated check Maroon had an infection of 80S at all locations.

Although Maroon had a slightly higher average 1000-kernel weight, it did not differ significantly from that of Gaher. However, Gaher significantly outyielded Maroon at all locations, except at Moghan, giving an average yield of 4138 kg/ha compared to 3489 kg/ha for Maroon. Table 1 shows that the new rust-resistant cultivar Gaher gives significantly higher and stable yield than Maroon and does not differ in other agronomic characteristics.

Table 1. Mean agronomic characteristics of cultivar Gaher at different research stations, 1995/96.

Station	Plant height (cm)	Lodging†	Maturity (days)‡	Rust Yellow	Rust Leaf	Rust Stem	1000-kernel wt (g)	Yield (kg/ha)
Gachsaran	89	R	M	10MR	20MR	–	32	4751
	(97)§	(R)	(E)	(80MS)	(60MR)	(–)	(35)	(3974)
CV (%)								11.27
LSD (1%)	89							533
Moghan	82	R	E	–	0	–	31	3445
	(86)	(R)	(E)	(80S)	(20S)	(–)	(34)	(3539)
CV (%)								10.06
LSD (1%)								437
Kohdasht	75	R	M	5MR	0	–	33	3869
	(83)	(R)	(E)	(80S)	(20S)	(–)	(33)	(3390)
CV (%)								5.07
LSD (1%)								366
Gorgan	90	R	M	5S	–	–	35	4585
	(93)	(R)	(M)	(80S)	(30MR)	(–)	(28)	(3540)
CV (%)								15.07
LSD (1%)								539

† R = Resistant.

‡ M = medium; E = early.

§ Figures in parentheses are for the check cultivar Maroon.

– = not observed.

The improved cultivar Niknegad

The mean results on the major agronomic traits of Niknegad and the check Maroon are given in Table 2. Mean plant height of Niknegad and Maroon was 92 and 89 cm, respectively, with no significant difference. Both cultivars are resistant to lodging.

Niknegad is medium in maturity while Maroon is early. The former had a maximum yellow rust infection of 10MS compared to 40S for the latter at Gachsaran. Maroon is highly susceptible to yellow rust, and an infection of 80S was observed at Gorgan compared to 10MR for Niknegad. Both cultivars expressed a moderately resistant reaction to leaf rust at all locations except Kohdasht where Maroon had an infection score of 20S. Grain color of both cultivars is amber, and their protein content is the same. However, 1000-kernel weight was different. The reduction in 1000-kernel weight of Maroon can be attributed to the heavy yellow rust infection which was also responsible for the low grain yield. At Gachsaran, Niknegad had lower 1000-kernel weight and grain yield than Maroon. This was probably due to the longer growth period and later maturity under Gachsaran conditions, where the temperature rises quickly in the spring and terminal moisture is severe. The low yield of Niknegad under Gachsaran climatic conditions is probably due to its lower tolerance to high temperatures and moisture stress compared to the locally adapted cultivar Maroon. Therefore, this variety is not suitable for areas where terminal moisture stress is severe and early maturity is needed.

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Table 2. Mean agronomic characteristics of cultivar Niknegad at different research station, 1995/96.

Characteristics Stations	Plant height (cm)	Lodging†	Maturity (days)‡	Rust Yellow	Rust Leaf	Grain color	Protein (%)	1000-kernel wt (g)	Yield (kg/ha)
Gachsaran	100	R	M	10MS	25MR	Deep amber	11.5	28.5	2051
	(97)§	(R)	(E)	(40S)	(60MR)	Amber	(11.6)	(30)	(2439)
CV (%)									11.62
LSD (1%)									336
Moghan	84	R	M	5MS	0	Deep amber	11.3	33.2	4083
	(81)	(R)	(E)	(50S)	(20MR)	Amber	(10.5)	(34)	(3539)
CV (%)									13.53
LSD (1%)									299
Kohdasht	81	R	M	0	0	Amber	11.7	38	5350
	(81)	(R)	(E)	(50S)	(20S)	Amber	(11.0)	(34)	(4600)
CV (%)									7.07
LSD (1%)									450
Gorgan	99	R	M	10MR	-	Deep amber	10.5	38	5736
	(97)	(R)	(E)	(80S)	(-)	Amber	(10.5)	(28)	(3200)
CV (%)									13.13
LSD (1%)									777

†, ‡, § See Table 1.

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Interspecific Differentiation of *Triticum* Species with Reference to Resistance to Leaf and Yellow Rusts

التفريق البينوعي لأنواع *Triticum* على أساس المقاومة لصدأ الأوراق والصدأ الأصفر

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Abstract

This report gives an account of results of long-term research relating to *Triticum* L. world species as sources for resistance to leaf and yellow rusts. All 26 natural wheat species known to date (ignoring artificial ones) are described; the most complex resistant samples are named. The reasons for unequal resistance in wheat species are discussed in light of up-to-date views on the evolution of *Triticum*. A method to synthesize a complex immune homologue of common wheat is pointed out.

الملخص

يقدم هذا التقرير عرضاً عن نتائج بحث طويل الأجل متعلق بالأنواع العالمية لـ .*Triticum* L كمصادر لمقاومة مرضيَ صدأ الأوراق والصدأ الاصفر. ويتم في الوقت الحاضر وصف جميع الأنواع الـ 26 من القمح الطبيعي المعروفة حتى الآن (مع تجاهل الأنواع الاصطناعية)، كما تجري تسمية معظم العينات المقاومة المعقدة. ويتم البحث في الأسباب الكامنة وراء عدم تساوي المقاومة في أنواع القمح في ضوء أحدث الآراء حول نشوء *Triticum*. كما أشير إلى إحدى الطرائق لتخليق مثيل للقمح الشائع من ناحية التركيب يكون معقداً ومنيعاً .

Key words: *Triticum*; varieties; diploidy; tetraploidy; hexaploidy; evaluation; disease resistance; immune complexes; Russian Federation.

Introduction

With the intensification of crop production, there is an urgent need to breed new wheat varieties to reduce damage from disease and produce stable yields. Among the diseases affecting wheat are leaf and yellow rusts—the latter being especially harmful. Research at the former Central Asiatic experimental station of N.I. Vavilov All-Russian Institute of Plant Industry (VIR) near Tashkent, Uzbekistan, showed that susceptible common wheat varieties of Central Asia lost their productivity during epiphytotics compared with cultivar Bezostaja 1 (Table 1).

Table 1. The productivity (g/m²) of bread-wheat varieties depending on the rate of development of leaf and yellow rusts.

Variety	Epihytoty of leaf rust	Epiphytoty of yellow rust	Absence of both rusts
Babilo	180	5	250
Kzyl-Shark	260	50	350
Krasnaja Zvezda	210	45	330
Graecum 289	200	10	310
Turcicum 1	200	30	340
Bezostaja 1	380	410	425

The most widely used method for breeding resistant wheat varieties has been intraspecific hybridization. As a rule, a race-specific resistance is used, since it is easily inherited and therefore is technically convenient, although it provides only short-term defense. Therefore, in all countries that have long experience in breeding and cultivating resistant wheat varieties, the same picture is observed of gradual (sometimes sudden) loss of resistance, and epiphytotic development of a parasite as a result of the reproduction of races virulent to a previously resistant variety. Thus, there is a constant search for effective donors and, therefore, interspecific hybridization including species of the *Triticum* genus. In interspecific crosses, the frequency of positive transgressions increases leading to more frequent resistant types. The resulting hybrid populations give rich material for selection. Breeders often refer to the fact that resistance genes of wheat are usually linked with genes that are harmful in breeding (e.g., brittleness of spike and filmy grain), but modern genetics has methods for breaking deleterious linkages and freeing genotypes of harmful genes (e.g., by exposing interspecific F_1 hybrids to ionizing radiation or chemical mutagens, that provides an interchange with useful chromosome segments).

Russia has the most complete world collection of wheat at VIR. The collection contains 26 "species" of *Triticum* (apart from the artificial ones) (Table 2). In this report, results of long-term studies made at the Institute on the interspecific differentiation of world resources of *Triticum* in their resistance to leaf and yellow rusts are presented. The resistance of the world wheat collection to these diseases was studied under natural field conditions in the experimental station of the Institute. The evaluation was made according to damage using the 5-point scale of N.I. Vavilov, i.e., 0 = no damage, 1 = weak damage, 2 = intermediate, 3 = over-intermediate and 4 = total damage.

Table 2. Wheat species and their genome composition.

Species group	Species	Genome composition
Diploid (2*n* = 14)	*T. boeoticum* Bioss.	A^b
	T. urartu Tum. ex Gandil.	A^u
	T. monococcum L.	A^b
	T. sinskajae Filat. et Kurk.	A^b
Tetraploid (2*n* = 28)	*T. dicoccoides* Koern. et Schweinf.	A^uB
	T. araraticum Jakubz.	A^bG
	T. timopheevii Zhuk.	A^bG
	T. dicoccum Schuebl.	A^uB
	T. ispahanicum Heslot	A^uB
	T. karamyschevii Nevski	A^uB
	T. militinae Zhuk. et Migusch.	A^bG
	T. turgidum L.	A^uB
	T. durum Desf.	A^uB
	T. turanicum Jakubz.	A^uB
	T. aethiopicum Jakubz.	A^uB
	T. polonicum L.	A^uB
	T. carthlicum Nevski	A^uB
	T. jakubzineri Udacz. et Schachm.	A^uB
Hexaploid (2*n* = 42)	*T. zhukovskyi* Men. et Er.	A^bGA^b
	T. macha Dek. et Men.	A^uBD
	T. spelta L.	A^uBD
	T. vavilovii Jakubz.	A^uBD
	T. compactum Host.	A^uBD
	T. sphaerococcum Perc.	A^uBD
	T. aestivum L.	A^uBD
	T. petropavlovskyi Udacz. et Migusch.	A^uBD

Diploid Species of *Triticum* (2*n* = 14)

The wild einkorns, *T. boeoticum* and *T. urartu*, are distinguished by their resistance to leaf rust, but differ in their resistance to yellow rust—the first form being highly resistant, while the latter is highly susceptible. It was N.I. Vavilov who named the cultivated einkorn *T. monococcum* "an accumulator of complex immunity to infectious diseases." Even now this statement is true, although some susceptibility to trans-Caucasian forms of leaf rust has been found (k-6411, 23653, 31566, 34598) and to European forms of yellow rust (k-20398, 29602, 39472, 46140). In 1975, a new diploid wheat "*sinskajae*" was described at this Institute by Drs A. Filatenko and U. Kurkiev. This wheat is a natural glabrous mutant of the Turkish sample *T. monococcum* and is characterized by a high level of resistance to both rusts. Despite its weak threshability, it may be possible to use the favorable characters of this form for breeding.

Tetraploid Species of *Triticum* (2*n* = 28)

The wild emmers, *T. dicoccoides* and *T. araraticum*, are susceptible to leaf and yellow rusts. However, there are forms of *T. dicoccoides* from Palestine (k-17256, 23665) with a high level of resistance. Cultivated emmer, *T. dicoccum*, includes a whole range of immunological differences with respect to rust: subsp. *asiaticum* is mostly susceptible to rusts, but there are resistant samples (k-13482, 13648) from Armenia; subsp. *maroccanum* is susceptible to yellow rust, but somewhat resistant to leaf rust (the same can be said about subsp. *volgense*, which includes the Volga and Balkan forms); in the range of subsp. *abyssinicum*, one of the most rust-resistant taxa, only the samples form India are characterized by a high susceptibility to yellow rust; and subsp. *europaeum* is also distinguished by complex immunity (only the forms from Bavaria are susceptible to leaf and yellow rusts). The endemic emmer *T. karamyschevii* (*T. palaeocolchicum*) from western Georgia is highly resistant to *Puccinia recondita* and *P. striiformis* and is therefore valuable for breeding. Contrarily, endemic emmer *T. ispahanicum* from Iran and *T. turanicum* (*T. orientale*) are highly susceptible. Within *T. aethiopicum* there is a considerable variation in resistance to rusts, and the most resistant samples are k-19036, 19070 and 43781. The same can be said about *T. polonicum*, which has resistant forms of convar. *eumediterraneum* (k-13520, 16414, 21162, 25646). *Triticum carthlicum* (*T. persicum*) generally has medium resistance to leaf and yellow rusts, but there are samples with complex immunity (k-1694, 13938, 34577). Within *T. turgidum*, forms susceptible to both rusts have been observed in convar. *iranicum*, and within other groups (convar. *meridionale*, *caspicum*, *occidentale—europaeum* and *sinicum*) the pattern is rather mixed and resistance occurs both in samples from the former USSR (k-13208, 13489, 18663, 19338, 40239) and Europe (k-20397, 38099, 40837, 43159, 43174, 45829).

In 1972, a new form, "*jakubzineri*," was distinguished by Drs R. Udachin and I. Shahmedov. It is a natural mutant from an Afghan sample of *T. turgidum* var. *lusitanicum* and is characterized by branching of spikes, as in *T. vavilovii*. It has a unique character within *Triticum*, namely, four glumes per spikelet; this species has insufficient resistance to leaf and yellow rusts. Among the tetraploid species of wheat, the champion in complex immunity is universally recognized as *T. timopheevii*. Until now, the thesis about phenomenal complex of resistance genes in this wheat is unchangeable (in VIR experiments the susceptibility to leaf rust up to score 1 was observed only in sample k-29653). In 1969, "*militinae*" was described by Acad. P. Zhukovsky and Dr E. Migushova. It is a natural glabrous mutant of *T. timopheevii* with compact spikes, and maintains the complex immunity of its parent. This gives the prospect of involving "*militinae*" in resistance breeding.

Hexaploid Species of *Triticum* (2*n* = 42)

Triticum zhukovskyi is distinguished by complex immunity, and *T. vavilovii*—that N.I. Vavilov named as "an accumulator of infection" (the same can truly be said about *T. sphaerococcum*)—by higher susceptibility. The form of endemic spelta, *T. macha*, from western Georgia is susceptible to leaf and yellow rusts. Across the range of *T. spelta*, Asiatic subspecies (subsp. *kuckuckianum*) is susceptible to both rusts, while the European speltas as a whole are resistant (especially samples k-20392, 20539, 20542, 20546, 20754, 45769), and convar. *asturicum* is more resistant than convar. *bavaricum*. *Triticum compactum* is more susceptible to *Puccinia recondita* and *P. striiformis* than common wheat, and resistance is typical only of single samples (k-14187, 15978, 45167). Endemic west-Chinese *T. petropavlovskyi* (distinguished in 1970 by Drs R. Udachin and E. Migushova), which is characterized by unequal length of palea and by presence of awn-like shoots in the glumes, is also highly susceptible to both rusts.

Durum and Bread Wheat

The VIR world collection samples of the two species that are major agricultural crops have different resistance to leaf and yellow rusts, depending on their origin. Table 3 shows the results of studies relating to this aspect. The following groups can be differentiated: (1) resistant samples with susceptibility scores 0 and 1; (2) medium-resistant samples with score 2; and (3) susceptible samples with scores 3 and

4. The forms of *T. durum* with maximum susceptibility to both rusts are from southwestern and eastern Asia, and the susceptible forms of *T. aestivum* from Asia Minor, the Near East and southwestern Asia. The durum wheat of Asia Minor and the Near East is more resistant than the bread wheat of the same region. The highest complex resistance of both wheat species as a whole occurs in samples from southern Europe and Latin America. Among the most complex resistant varieties of durum wheat are the Italian varieties Capeiti 8, Maliani 1, Maliani 12D and Maliani 17; the Portuguese Pardabeiro and Preto Amarelo; the Canadian Picture and R.D.3-2; the US Lacota; the Moroccan Zeramek and Selbera; the Algerian samples k-16270 and 16320; and the Chilean variety P.B.458. Among bread wheats, the Dutch variety Orca; the West German Claudius; the Czechoslovakian Zlatka; the Swiss Hinal; the Italian Produttore, Funone and Furio; the Portuguese Pirana; the Indian Kalyan Sona, Chhoti Lerma and P.V.18; the Canadian Manitou, ISWRN 92 and ISWRN 225; the US Rudorf and Fronthutch; the Mexican Jaral 66, Tobari 66, Ciano 67 and Nadadores 63; the Chilean Llocofen, Kenyafen, P.B.16, P.B.48 and P.B.311; the Brazilian Frontana, Toropi, Cotipore and Nova Prata; the Argentinian Vencedor, Klein Ceres and El Gaucho; the Kenyan Kenya Hunter; and the Australian Modesty, Rapier 48, Scimitar 48 and Timgalen.

Therefore, the various species of *Triticum* show unequal resistance to leaf and yellow rusts. This can be mostly explained by different origins and evolutionary pathways. Much work has been done to establish the evolution of *Triticum*, including studies made at our Institute. As a result, we now consider that at least five primary forms took part in the origin and development of modern polyploid wheat

Table 3. Differentiation of bread- and durum-wheat samples according to resistance to leaf and yellow rusts (% of diseased samples per each group).

Geographical region	Wheat	Group of disease of rust (score)					
		Leaf			Yellow		
		0–1	2	3–4	0–1	2	3–4
West Europe and Scandinavia	common	50	44	6	94	3	3
	durum	–	–	–	–	–	–
East and Central Europe	common	57	36	7	91	6	3
	durum	89	11	–	83	17	–
South Europe	common	69	23	8	81	10	9
	durum	79	17	4	87	11	2
North Africa	common	56	30	14	40	4	56
	durum	91	9	–	92	4	4
East Africa	common	82	18	–	67	11	22
	durum	–	–	–	–	–	–
Asia Minor and the Near East	common	20	33	47	9	17	74
	durum	83	12	5	77	13	10
Southwest Asia	common	21	32	47	15	33	52
	durum	20	60	20	10	35	55
East Asia	common	40	51	9	42	12	46
	durum	25	75	–	–	20	80
Oceania and South Africa	common	73	23	4	39	14	47
	durum	100	–	–	66	17	17
North America	common	57	34	9	69	16	15
	durum	100	–	–	46	15	39
Latin America	common	96	3.5	0.5	93	4	3
	durum	100	–	–	82	11	7

species (Table 2). A wild einkorn *T. urartu* was the donor of the first genome, A^u, for the primary tetraploid of the *T. dicoccum* group, and *Aegilops longissima* was the donor of their second genome, B. Simultaneously, donors for the primary tetraploids of the *T. timopheevii* group were *T. boeoticum* (A^b genome) and *Ae. speltoides* (G genome). The development of hexaploid wheat also occurred twice: the *T. spelta* group had as a donor of their third genome, *Ae. taushii* (D genome), which the cultivated einkorn, *T. monococcum* (A^b genome), was the donor of the third genome to *T. zhukovskyi*.

As a result, tetraploids with A^uB content were transformed by nature into three genomes (A^uBD), and tetraploids with A^bG content to hexaploid level with two genomes (A^bGA^b) (Table 2).

The regularity of *Triticum* evolution gives new possibilities for the synthesis of a complex immune homologue of bread wheat. One such way is the unity of the *T. militinae* genotype with resistant forms of *Ae. taushii*. In Japan, a homologue of *T. spelta* resistant to leaf and yellow rusts, with genome content A^bGD has been developed by crossing *T. timopheevii* with *Ae. taushii*. This amphyploid was identified in 1977 at our Institute by Drs V. Dorofeev and E. Migushova as an independent species, *T. kiharae*.

Effect of Aqueous Leaf Extract of Field Bindweed (*Convolvulus arvensis* L.) and Salinity on Growth of Wheat

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Abstract

Aqueous leaf extract of field bindweed (*Convolvulus arvensis* L.) was evaluated alone and in combination with NaCl for its effect on germination and seedling growth of wheat (*Triticum* sp.). There was no effect of salinity or the aqueous leaf extract on seed germination. Leaf extract alone also did not have any effect on shoot growth, but salinity alone or in combination reduced it. However, the differences in the effects of 0.2% NaCl + extract and 0.4% NaCl + extract were entirely attributable to the difference in NaCl concentration. Root growth was reduced by both salinity and leaf extract. The reduction due to salinity was more under 0.4% than 0.2%, and leaf extract caused a reduction of about 40% irrespective of whether it was applied separately or in combination.

Key words: wheats; *Convolvulus arvensis*; leaves; plant extracts; salinity; roots; stems; growth; Pakistan.

تأثير مستخلص مائي من أوراق اللبلاب الحقلي (*Convolvulus arvensis* L.) والملوحة في نمو القمح

الملخص

تم تقييم تأثير مستخلص مائي من أوراق اللبلاب الحقلي (*Convolvulus arvensis* L.) بمفرده أو مع الملح (NaCl) في إنبات ونمو بادرات القمح (*Triticum* sp.). ولم يكن للملوحة أو المستخلص المائي للأوراق تأثير في إنبات البذور. كما أن مستخلص الأوراق بمفرده لم يكن له أي تأثير في نمو الفروع، أما الملوحة بمفردها أو مع المستخلص فقد أدت إلى خفضه. غير أن الفروق بين تأثير 0.2% ملح + المستخلص و 0.4% ملح + المستخلص، كانت ناتجة كلية عن الفرق بين تراكيز الملح. وقد انخفض نمو الجذور تحت تأثير كل من الملوحة ومستخلص الأوراق. وكان الانخفاض الناتج عن الملوحة أكبر تحت تأثير 0.4% منه تحت تأثير 0.2%، وأدى مستخلص الأوراق إلى انخفاض بمقدار حوالي 40% سواء أضيف على حدة أو مع الملح.

Introduction

Crops and weeds are known to exhibit allelopathy by releasing water-soluble phytotoxins from leaves, stems, roots, rhizomes, flowers, fruits, seeds and glandular trichomes (Alam 1990a,b; Alam et al. 1990; Sterling et al. 1987). Weeds which compete with crop plants for nutrients and environmental variables appear to be toxic to the germination and growth of the plants. The allelopathic potential of several weeds has been studied in the laboratory and in the field (Bhowmik and Doll 1984; Alam 1990a,b; Azmi and Alam 1989). LeTourneau et al. (1956) report that water extracts from 23 common weed and crop residues inhibited germination and growth of wheat seedlings, and the phytotoxic effect of 14 aqueous root extracts on germination and seedling length of 15 plant species is recorded by Lawrence and Kilcher (1962). The phytotoxic effects can be attributed either to allelochemicals present in the plant or weed residues, or to microbial toxins produced during decomposition (Rice 1984). In field crops, the common allelopathic effects are reduced germination, lack of seedling vigor, seedling death, leaf yellowing and growth, and deformed roots or tops (McCalla and Haskins 1964).

Convolvulus arvensis, commonly known as field bindweed, is an important annual weed with a climbing and prostrate growth habit. It is distributed throughout the temperate and tropical regions, and is found in Pakistan in almost every field in winter. It binds many tillers together and hinders the normal growth of crops.

Earlier studies on allelopathic effects of weeds have been carried out under normal growth conditions, but there seems to be no report on crop plants growing under saline or marginal land conditions. This is of special significance in Pakistan, where salinity is extensive. It is well known that salinity adversely affects plant growth. The objective of this work was to ascertain the effects of aqueous leaf extract of *C. arvensis* in the presence or absence of NaCl on the germination and seedling growth of wheat.

Material and Methods

Fresh leaves of field bindweed (*Convolvulus arvensis* L.) were collected from a wheat field, washed with water and dried in an oven at 70°C for 24 h. Dried samples were ground in a Wiley mill to pass through a 20 mesh screen. The aqueous extract was prepared by soaking 5 g of the material in 100 ml distilled water for 24 h, then filtered with Whatman filter paper No. 42 and kept in a reagent bottle. Five ml of extract was added to a 0.8% sterilized agar medium adjusted to 0, 0.2, or 0.4% NaCl. Two other treatments having the same NaCl levels, but without aqueous leaf extract, were also prepared. For each of the preparations, 50 ml was poured into a glass bowl. The treatment with only agar, i.e., contanining no NaCl and/or aqueous leaf extract, was considered as the control. Seeds of wheat (cv Pavon) were sterilized with 1% sodium hypochlorite for 3 min and then rinsed with distilled water. Ten seeds of wheat were planted in a circle on the surface of each bowl, with the embryo side up and pointing inwards. The bowls were covered with petri dishes and incubated at 28°C for 120 h. The glass bowls were randomized and each treatment was replicated four times. Germinated seeds were counted and their shoot and root lengths were measured.

Results and Discussion

The aqueous leaf extract of field bindweed alone or in combination with NaCl had no effect on seed germination. Similarly, compared to the control, the leaf extract alone had no effect on shoot growth, but NaCl salinity alone or in combination with leaf extract reduced shoot length. However, the differences in shoot growth due to the effects of 0.2% NaCl + extract and 0.4% NaCl + extract were absolutely attributable to the differences in NaCl concentration. Compared to the control, leaf extract alone significantly decreased root growth of the seedlings by 62% (Table 1). At 0.2% NaCl with leaf extract, the reduction in root growth was 59% compared to 0.2% NaCl alone. Similarly, at 0.4% NaCl with leaf extract, the reduction in root growth was 58% over that at 0.4% NaCl alone.

Table 1. Effect of aqueous leaf extract of field bindweed (*Convolvulus arvensis* L.) and NaCl on germination and seedling growth of wheat.

Treatment†	Germination (%)	Shoot length (cm)	Root length (cm)
Control (no leaf extract, no NaCl)	85 a‡	8.32 a (–)	7.61 a (–)
Leaf extract alone	90 a	8.42 a (1.20)§	2.92 d (–61.6)
0.2% NaCl alone	90 a	6.95 b (–16.5)	6.41 b (–15.8)
0.2% NaCl + leaf extract	90 a	6.86 b (–17.5)	2.65 e (–65.2)
0.4% NaCl alone	95 a	5.41 c (–34.9)	4.19 c (–44.9)
0.4% NaCl + leaf extract	88 a	5.40 c (–35.1)	1.74 f (–77.1)

† 250 mg leaf extract/50 ml of 0.8% agar gel.
‡ Values followed by the same letter do not differ significantly at 5% level (Duncan's Multiple Range Test).
§ Figures in parentheses indicate percentage decrease from the control.

These results suggest that the inhibitory effect on root growth was due to water-soluble phytotoxins leached from the leaf residue. Root growth was *affected more than* shoot growth, which shows that combined stresses of leaf extract and NaCl had synergistic effects on root growth of wheat plants.

Root growth was affected more than shoot growth, because the roots were in direct contract with the extract when incorporated and were thus exposed to allelochemicals. Incorporation may also increase decomposition by micro-organisms which may release or produce allelochemicals from the residue which would also affect root growth. Rice (1984) reported that aqueous extract caused injury when the extract was in contact with or in the immediate vicinity of plant root. Bhowmik and Doll (1982) reported that residues of common lambsquarters, redroot, pigweed, velvetleaf, soybean and sunflower reduced soybean yield. The yield reductions ranged from 14% with velvetleaf to 19% with sunflower residues. Conversely, residues of giant foxtail and corn enhanced soybean yield by 16 and 19%, respectively. There are also reports that growth inhibition, such as reduction in cell division (Avers and Goodwin 1956) or auxin-induced growth of roots (Geissman and Phinney 1972), is caused by allelochemicals. This could be due to direct inhibition of nutrient absorption (Glass 1973), to direct interference with respiration or oxidative phosphorylation (Demos et al. 1975), or be related to photosynthesis (Bhowmik and Doll 1984; Patterson 1981).

Conclusions

Aqueous leaf extracts of field bindweed alone or in combination with NaCl significantly reduced root growth of wheat. It is therefore necessary to uproot this weed from experimental fields when growing wheat under normal or saline conditions.

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Agronomic Performance of Durum-Wheat Varieties in Le Kef, Tunisia

الكفاءة الزراعية لأصناف من القمح القاسي في الكيف بتونس

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Abstract

A field evaluation of three introduced (Om Rabi 3, Om Rabi 5 and Chen"s"/Altar) and three commercial durum-wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) varieties (Razzak, Karim and INRAT 69) was conducted at Le Kef location in the semiarid areas of Tunisia during two seasons, 1991/92 and 1993/94. Findings revealed genotype variability for all characters except days to heading (1991/92) and kernels/spike (1993/94). Karim and Razzak gave the best grain yield in the 1991/92 favorable season with 1000-kernel weight and spikes/m as the main contributors. However, Om Rabi 3 and Om Rabi 5 were superior in grain yield in the 1993/94 unfavorable season, with the highest performance in plant height and spikes/m. Generally, INRAT 69 and Khiar 92 (Chen"s"/Altar) had worse performance in most of the agronomic characters in both seasons. Thus, Razzak and Karim can be retained as good-performing varieties in favorable seasons and Om Rabi 3 in unfavorable seasons. At the same time, they can be used in order to reduce the effect of climatic variation and improve grain yield stability in the semiarid areas of Tunisia.

الملخص

أجري تقييم حقلي لثلاثة أصناف مُدخلة من القمح القاسي (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) (أم ربيع 3، أم ربيع 5 ، وشين ´S´/ألتار) وثلاثة أصناف تجارية (رزاق ، كريم ، وإنرات 69) في موقع الكيف في المناطق شبه الجافة من تونس خلال الموسمين الزراعيين 1991/92 و1993/94. وكشفت النتائج عن تفاوت بين الطرز الوراثية بالنسبة لجميع الصفات باستثناء عدد الأيام حتى الإسبال (1991/92) وعدد الحبات/السنبلة (1993/94). وقد أعطى كريم ورزاق كمساهمين رئيسيين أفضل غلة حبية في الموسم المواتي 1991/92 فضلاً عن وزن الـ 1000 – حبة وعدد السنبلات/م. غير أن أم ربيع 3 وأم ربيع 5 تفوقا في الغلة الحبية في الموسم غير المواتي 1993/94 واتسما بأعلى كفاءة في طول النبات وعدد السنبلات/م. وبصورة عامة، اتصف إنرات 69 وخيار 92 (شين ´S´/ألتار) بكفاءة أدنى في معظم الصفات الزراعية في كلا الموسمين. لذلك يمكن اعتبار رزاق وكريم كصنفين جيدي الأداء في المواسم المواتية وأم ربيع 3 في المواسم غير المواتية. وفي الوقت نفسه، يمكن استعمالهم بغية تخفيض تأثير الاختلاف المناخي وتحسين استقرارية الغلة الحبية في المناطق شبه الجافة من تونس.

Key words: *Triticum durum*; varieties; genetic variation; agronomic characters; grains; yields; crop performance; semiarid zones; Tunisia.

Introduction

The semiarid areas of Tunisia, mainly Le Kef and Siliana, are characterized by low annual rainfall with a long-term average of 350 mm. However, the major problem is the wide year-to-year variability in total rainfall (200–600 mm) and distribution throughout the season (Mâamouri et al. 1988).

The main varieties cultivated by farmers are Razzak, Karim and INRAT 69, which have been selected and tested in Tunisia. Recently, three introduced varieties were tested in Tunisia: Chen"s"/Altar, Om Rabi 3 and Om Rabi 5. Only Chen"s"/Altar (Khiar 92) and Om Rabi 3 were released.

The Tunisian varieties are considered as high-yielding germplasm especially in high-rainfall areas. Razzak and Karim could positively respond to incremental amounts of nitrogen according to their excellent spike fertility, short plant height and large kernel size (Mâamouri et al. 1988). Therefore, they are suitable for irrigated and high-rainfall regions. INRAT 69 yields less than Razzak and Karim and is characterized mainly by tall plants (Mâamouri et al. 1988).

Khiar 92 is not widely adopted by farmers in these regions up to now. It has demonstrated high-yielding performance under unfavorable conditions during three seasons (ICARDA 1991). Nevertheless, other experiments concluded that Khiar 92 gave the best yield under high-rainfall conditions (Gharbi 1993).

Nachit et al. (1992) indicated that Om Rabi lines 3, 5 and 6 are adapted to the Mediterranean drylands. Research in the semiarid areas of Tunisia has allowed confirmation of Om Rabi cross for withstanding the late drought of the year (Mekni 1993). Om Rabi 3 has high and stable yields in Mediterranean continental drylands (Nachit et al. 1992) and resistance to abiotic stresses (ICARDA 1993). It was released in 1993 for semiarid areas of Tunisia. Om Rabi 5 was also tested in these regions and then rejected.

This study was undertaken to evaluate the agronomic performance of three introduced and three commercial varieties under two different conditions in the semiarid region of Le Kef.

Material and Methods

The trial consisted a six entries: three introduced from ICARDA (Om Rabi 3, Om Rabi 5 and Khiar 92-Chen"s"/Altar) and three widely adopted in Tunisia (Razzak, Karim and INRAT 69). The experiment, which was conducted under rainfed conditions at Le Kef Research Station of INRAT during two seasons, 1991/92 and 1993/94 (Table 1), was laid out in a randomized complete block design with four replications and the plot size was 3.75 m^2. Seeding was in six rows, 25 cm apart, at the rate of 250 kernels/m^2. Fertilizers were applied at the rate of 120 kg N and 100 kg P/ha.

Data were recorded on grain yield, plant height, 1000-kernel weight, number of kernels/spike, number of spikes/m and days to heading, counted from 1 January to heading. Grain yield was recorded from a length of 2 m from each of the middle 4 rows (total = 2 m^2). Analysis of variance was made for each character and comparison between varieties was based on the LSD criterion.

Results and Discussion

No significant differences were found in the replications for all characters and seasons (Tables 2 and 3). This fact indicated the high precision of the experiment. However, there were significant differences among genotypes in all characters except days to heading in 1991/92 (Table 2) and number of kernels/spike in 1993/94 (Table 3).

Table 1. Monthly precipitation (mm) from September to May at Le Kef during the 1991/92 and 1993/94 seasons.

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1991/92	56.5	52.6	32.6	16.1	28.4	62.3	33.1	95.8	82.1
1993/94	21.7	19.7	8.0	30.2	31.2	77.8	10.7	23.1	13.4

Table 2. Analysis of variance for durum wheat agronomic traits, 1991/92.

Source of variation		Mean squares†					
	df	GY	PH	TKW	KS	SM	DH
Genotype	5	144.36**	119.17**	133.0**	20.60*	127.94**	1.80 ns
Replication	3	21.80 ns	40.28 ns	0.11 ns	9.33 ns	28.93 ns	2.27 ns
Error	15	8.9	18.61	1.08	4.73	20.49	0.71

†GY = grain yield; PH = plant height; TKW = 1000-kernel weight; KS = number of kernels/spike; SM = number of spikes/m; DH = days to heading.
*, ** significant at 5 and 1% level, respectively; ns = not significant.

Table 3. Analysis of variance for durum wheat agronomic traits, 1993/94.

Source of variation		Mean squares†					
	df	GY	PH	TKW	KS	SM	DH
Genotype	5	51.5*	51.6**	37.70**	30.2ns	218.90**	18.16**
Replication	3	4.9 ns	12.5 ns	0.15 ns	31.0 ns	58.55 ns	0.72 ns
Error	15	13.6	10.0	6.3	13.4	19.45	1.92

†, *, ** See Table 2.

1991/92 season

The mean values of the agronomic characters are shown in Table 4. Grain yield and 1000-kernel weight were maximum in Razzak (38.8 q/ha [3,880 kg/ha] and 51.8 g, respectively) and Karim (37.0 q/ha [3,700 kg/ha] and 51.8 g, respectively). Maximum plant height was found in INRAT 69 (101.2 cm) while all the other genotypes had the same performance. The largest number of spikes/m was observed in Razzak and Karim, 58.7 and 58.5, respectively, and lowest in Om Rabi 5 (41.7). Om Rabi 3 and Khiar 92 had the maximum number of kernels/spike, 47.7 and 45.7, respectively.

These findings reveal the superiority of Karim and Razzak for grain yield in this favorable season, as suggested by Mâamouri et al. (1988). This performance was obtained with large 1000-kernel weight and number of spikes/m. However, their plants were short, even in favorable conditions.

Om Rabi 3, INRAT 69 and Khiar 92 exhibited lower grain yield under these conditions because of their poor performances in most of the characters noted above. The best results in spike fertility (Om Rabi 3 and Khiar 92) and plant height (INRAT 69) were not enough to give high yield. On the other hand, Om Rabi 5 had moderate performance in all characters, which explains the low grain yield.

1993/94 season

The results of this season are presented in Table 5. The introduced varieties Om Rabi 3 and Om Rabi 5 had the maximum grain yield, plant height and number of spikes/m, with respective values of 25.6 and 25.8 q/ha (2,560 and 2,580 kg/ha), 90.0 and 87.5 cm, and 63.2 and 61.0. The best performance in plant height and days to heading were observed for INRAT 69, while Khiar 92, Razzak and Karim exhibited the lowest performance in all characters except 1000-kernel weight, with 41, 45 and 44 g, respectively.

This season was unfavorable; thus, it may be concluded that Om Rabi lines give the best results for grain yield and straw in low-rainfall conditions as mentioned by Nachit et al. (1992). INRAT 69 had approximately the same behavior as in 1991/92, with the highest performance only for plant height, which confirms the findings of Mâamouri et al. (1988).

Table 4. Mean values of agronomic traits for six durum-wheat varieties, 1991/92.

Variety	GY† (q/ha)‡	PH (cm)	TKW (g)	KS	SM	DH
Om Rabi 5	26.8 b§	86.2 b	48.6 b	46.0 bc	41.7 c	106.3 a
Om Rabi 3	26.6 b	90.0 b	49.4 b	47.7 a	48.2 bc	107.0 a
INRAT 69	28.2 b	101.2 a	41.4 c	42.2 c	51.0 abc	107.5 a
Khiar 92	24.6 b	88.7 b	38.1 d	45.7 ab	49.5 abc	107.0 a
Razzak	38.8 a	88.7 b	51.8 a	42.0 c	58.7 a	107.2 a
Karim	37.0 a	87.5 b	51.8 a	43.2 bc	58.5 a	107.5 a
LSD	6.22	8.99	2.16	3.27	9.44	–

† See Table 2.
‡ q = quintal, 1 q = 100 kg.
§ Values within a column followed by the same letter(s) are not significantly different.

Table 5. Mean values of agronomic traits for six durum-wheat varieties, 1993/94.

Variety	GY† (q/ha)‡	PH (cm)	TKW (g)	KS	SM	DH
Om Rabi 5	25.8 a§	87.5 a	37.2 b	41.0 a	61.0 a	104.0 b
Om Rabi 3	25.6 a	90.9 a	38.2 b	40.5 a	63.2 a	106.2 b
INRAT 69	18.4 b	85.0 a	36.7 b	41.5 a	44.7 b	109.7 a
Khiar 92	18.6 b	76.2 b	41.0 b	41.5 a	48.5 ab	106.7 b
Razzak	20.0 b	76.2 b	45.0 a	37.5 a	51.0 b	105.7 b
Karim	18.1 b	77.5 b	44.0 a	37.2 a	49.5 b	104.0 b
LSD	5.55	5.23	6.59	–	9.20	2.89

† See Table 2.
‡, § See Table 4.

The lowest yields registered by Khiar 92, Razzak and Karim were explained by the poor performance in most of the characters. The large 1000-kernel weight of Karim and Razzak, even under such conditions, indicate that they have large kernel size.

Conclusion

Findings from this study demonstrated that durum-wheat varieties responded differently to different environments in the semiarid areas of Tunisia. Therefore, INRAT 69 and Khiar 92 must not be adopted in these regions. However, Om Rabi 3 (released) can be retained as a good-performing genotype in low-rainfall seasons, and Karim and Razzak in high-rainfall seasons. Since the climatic characteristics of the season cannot be predicted, these varieties can all be used at the same time. This way the effect of climatic variations can be reduced and grain yield stability improved.

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Short Communications

Heritability and Genetic Advance in Barley under Partially Reclaimed Saline–Sodic Soil

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Barley (*Hordeum vulgare* L. subsp. *vulgare*), a hardy crop of ancient origin, is grown worldwide for food, feed and forage under varying agroclimatic conditions, such as in rain-fed areas, dry lands, saline–alkaline problematic soils and flood-prone marginal and coastal areas. Barley has an advantage over wheat in terms of yield and quality of B-glucon, soluble fiber protein, lysine and malt extract, and for its cooling and soothing effect. Under limited resources, barley affords lower cost of cultivation and better price.

The success that a plant breeder can achieve depends on the correspondence between phenotypic and breeding value. Its absence renders selection ineffective. Besides, heritability coupled with genetic advance gives an idea of the possible improvement of new populations through selection. Therefore, identification of desirable populations was the prime aim of the present investigation.

The material used in this study included seven homozygous and genetically diverse varieties of barley collected from CS Azad University of Agriculture and Technology in Kanpur; ARS Durgapura in Rajasthan; IARI in New Delhi; and ND University of Agriculture and Technology in Kumarganj, Faizabad. Four crosses, namely, NDB 90 × Ratna, NDB 90-1 × Jagrati, NDB 940 × RD 2516 and NDB 206 × BL-2 were made in 1995/96, while P_1, P_2, F_1, F_2, B_1 and B_2 generations were evaluated in 1996/97 at the Genetics and Plant Breeding Research Farm of ND University of Agriculture and Technology in Kumarganj, Faizabad. At the time of raising the crop, the soil was saline–sodic with pH of 8.4–8.9 and ECe of 4.2–4.6 mmhos/cm.

The standard package of practices for raising a good crop was followed. Five randomly selected plants of P_1, P_2 and F_1 generations and 20 plants each from back crosses and F_2 generations in a replication were tagged and data were recorded on 10 traits (Table 1). Heritability in the broad sense was calculated according to the formula suggested by Hanson et al. (1956), while genetic advance was calculated according to Johnson and Hayes (1955).

Broad-sense heritability ranged from 3.9% (days to maturity) to 97.8% (grain yield per plant). High heritability coupled with high genetic advance was noted for the number of effective tillers/plant in crosses II and III; length of spike in crosses II, III and IV; number of spikelets/main spike in cross II; and grain yield/plant in all crosses studied. During selection, it is considered that traits having high heritability coupled with high genetic advance are more dependable, while for others, the intensity of selection should be increased. High heritability with low genetic advance indicates the presence of non-additive gene action. Therefore, selection in early generations for these traits may not be effective.

Table 1. Heritability and genetic advance in percent of mean for 10 traits.

Character	Broad-sense heritability (%)				Genetic advance (%)			
	Cross I	Cross II	Cross III	Cross IV	Cross I	Cross II	Cross III	Cross IV
Days to ear emergence	95.7	81.0	89.8	91.6	15.10	6.44	11.02	11.34
Plant height	96.9	60.9	58.5	61.5	18.53	9.10	7.39	8.01
Days to maturity	93.0	3.9	84.8	85.5	3.34	0.18	2.84	3.90
No. effective tillers/plant	65.1	83.4	74.9	68.5	30.27	40.02	32.13	33.44
Length of spike	64.4	87.4	82.8	78.3	12.93	25.07	23.83	19.53
No. spikelets/main spike	72.3	89.5	77.4	86.4	15.63	25.90	16.35	17.19
Wt of grains/main spike	81.7	84.2	72.7	15.2	11.93	14.73	11.95	1.64
No. grains/main spike	59.2	72.8	97.5	86.4	9.44	16.89	17.63	14.18
1000-grain wt	30.2	57.7	53.3	40.4	2.32	6.31	4.68	3.14
Grain yield/plant	97.7	97.8	97.8	97.8	46.36	44.17	40.80	43.96

The findings of Thomas and Tapsell (1983) revealed that a high magnitude of heritability in segregating generations would be more helpful to the breeder in selection practices. High genetic advance along with high heritability was also reported by Aidum et al. (1990) and Pathak and Name (1985). Panse (1957) suggested that if heritability were largely a function of additive effects, it would be associated with high genetic advance because heritability in the broad sense alone is not sufficient to indicate the fixable portion of variability present in any population. Such expectations were further supported by Gandhi et al. (1964).

The overall results suggest that in the present case, selection based on the number of effective tillers/plant, length of spike, number of spikelets/main spike and grain yield/plant would be most fruitful for improvement of existing populations.

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Physiological and Productive Characters in Barley under Saline–Alkaline Soil

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Prior to the green revolution in India, barley (*Hordeum vulgare* L. subsp. *vulgare*) was the major staple cereal. This crop has great elasticity for adaptation and is a hardy, versatile cereal. It is more productive under limited resources of fertilizer and irrigation water. Hence, the areas with salinity and alkalinity problems, rainfed areas and dry lands, which still exist in the country, can be utilized by barley. This requires concentrated efforts and investment on network research for obtaining salt- and alkali-tolerant barley varieties, and designing an appropriate strategy for its wider adaptation.

A field experiment was conducted in 1992/93 and 1993/94 in saline–alkaline soil with nine entries, including three national checks, in a randomized block design with four replications at the Genetics and Plant Breeding Farm of ND University of Agriculture and Technology in Kumarganj, Faizabad. Sowing took place in the second fortnight of November. Row-to-row and plant-to-plant distances were kept at 23 and 10 cm, respectively. All cultural practices for raising a good crop were used. Some physiochemical properties of the experimental plot are depicted in Table 1, which reveals wide variation in soil fertility and salinity–alkalinity levels.

Table 1. Some physiochemical properties of the experimental plot.

Soil property	Value (range)
pH (1:1)	8.9–9.3
EC (dSm^{-1})	4.2–4.4
Organic carbon (%)	0.25–0.28
CEC (meq 100 g^{-1})	12.0–12.2
ESP	50.8
Soil texture	Silty loam

Under field conditions, besides auxiliary yield-contributing characters, crop growth rate and leaf area index

Table 2. Physiological and productive characters of barley.

Serial No.	Variety	Days to maturity	1000-grain weight (g)	CGR† (g day^{-1})	LAI‡ m^2m^{-2}	Yield (q/ha)§	Rank
1	Kharchia-65 (NC)¶	134	39.4	2.50	3.14	28.68	3
2	KRL-4 (NC)	124	39.6	2.60	3.00	24.44	8
3	NDB-217	111	39.8	2.00	2.17	19.20	9
4	RD-2514	124	42.0	2.10	2.50	25.28	6
5	RD-2515	116	39.2	2.00	2.65	28.20	5
6	NDB-209	116	40.4	2.52	3.80	29.16	2
7	Billara-2 (NC)	110	44.0	2.50	2.80	28.32	4
8	RD-2516	118	44.0	2.62	3.90	30.03	1
9	HD 2513	118	52.0	2.10	2.60	25.12	7

† CGR = crop growth rate.
‡ LAI = leaf area index.
§ q = quintal, 1 q = 100 kg.
¶ NC = national check
CV = 19.67%

were studied in the varieties. The latter two characters were determined by collecting representative samples from the field.

The analysis of variance showed that no significant differences were found between the yield of two new selections. NDB-209 and RD-2516 performed well and gave the highest yield compared to the other varieties (Table 2). Furthermore, it was noted that leaf area index is closely associated with the crop growth rate value, and this was reflected on the yield response of the varieties. These two entries and Kharchia 65 (national check) had the highest values of leaf area index. However, there is a need to describe these entries along with other morphological and physiological characters.

The exploitation of salt-affected soil is heavily dependent on manipulating the stressed edaphic environment. This is possible by genetically adapting the plants to saline–sodic conditions (Tiwari 1986). Sodic soil adversely affects plant growth and development mainly due to nutritional imbalance and severely restricted root system owing to the poor soil physical condition and high alkalinity.

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Agronomic Traits in Barley Grown under Residual Moisture in Ethiopia

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Barley (*Hordeum vulgare* L. subsp. *vulgare*) is one of the major cereal crops grown in Ethiopia. It is produced three times a year, June to September (main-season barley), March to May (short-season barley) and from September to January under residual moisture (locally known as *Mesno Gebs*). The main season accounts for about 80% of barley production. Cultivation of *Mesno Gebs* barley under residual moisture is commonly practiced in Gojam, Gonder and Wellega administrative regions. The yield level of *Mesno Gebs* under farmers' management is low, ranging from 0.3 to 0.5 t/ha. However, *Mesno Gebs* is the only crop that makes use of residual moisture for production in regions like Wellega where crops like chickpea (*Cicer arietinum* L.) and grasspea (*Lathyrus sativus* L.) are not grown. In some areas, continuous high rainfall in the main season associated with high disease development forces the farmers to delay planting until the rain starts to ease off. Moreover, smut and barley leaf stripe incidence is reduced by 99 and 86%, respectively, in the main-season barley when *Mesno Gebs* is used as its seed source (Bekele 1993).

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Screening of barley germplasm under residual moisture in northwestern Ethiopia was initiated at Adet Agricultural Research Center in 1990. In barley growing under low soil moisture, early and tall genotypes are related with high yield (Hadjichristodoulou 1987; Singh et al. 1986). Long-term studies are needed for each trait in order to determine the optimum range of values to be used in selection at a particular site and season.

Preliminary experiments were conducted on the association of grain yield with other traits in barley grown under residual moisture. Seventeen genotypes from previous evaluations of local landraces were tested at Adet Research Center in 1991/92. Rainfall received during the test was less than the long-term (seven years) average (Fig. 1). The experiment was laid out in a randomized complete block design with three replications. The plot size was 3 m^2, i.e., six rows at 20 cm spacing. The barley genotypes were sown on 30 September 1991 at a seed rate of 100 kg/ha. Fertilizer was applied at the rate of 69 kg N and 30 kg P/ha. The number of days to flowering and maturity was scored on plot basis. Plant height, peduncle length, spike length and number of grains per spike per plot were measured on spikes randomly selected from the four central rows. The four central rows per plot were also harvested for kernel weight and grain yield evaluation. Statistical analysis was carried out for each trait and simple correlation coefficients among the different characters and between grain yield were calculated.

Mean, range and coefficient of variation of 12 traits measured on 17 barley genotypes grown under residual moisture are presented in Table 1. The genotypes differed significantly in all traits including grain yield. The genotypes took an average of 109 days to mature, 70 days for vegetative growth and 39 days for grain filling. Barley genotypes grown under semiarid climates have been found to take 60% of their growth period for vegetative growth and 40% for grain filling (Samarrai et al. 1987). The range of maturity, vegetative and grain-filling periods among all the genotypes was 18, 26 and 17 days, respectively. The total variability in days to maturity was less than in days to heading. The difference in the grain-filling period among the genotypes was largely due to the difference in the vegetative period. This was suggested by the range (Table 1) and correlation value (Table 2). The grain-filling period was negatively correlated with the vegetative period, but it did not correlate with days to maturity. Samarrai et al. (1987) and Metzger et al. (1984) reported similar results. Days to maturity was positively correlated with the vegetative period, indicating that late-maturing genotypes tend to have a long vegetative period.

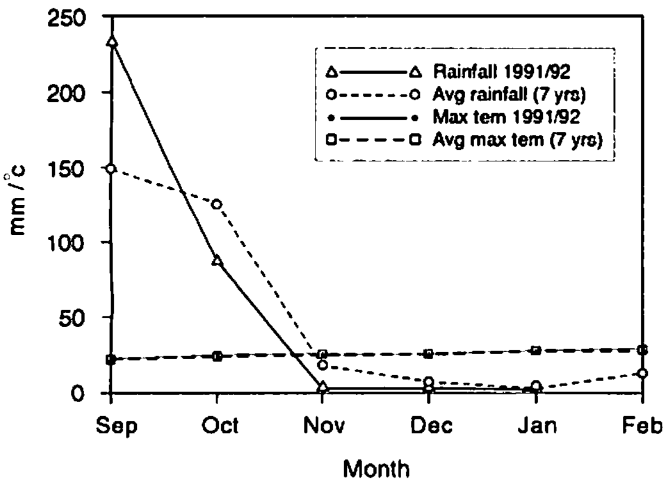

Fig. 1. Total rainfall and daily maximum temperature, Adet Research Center, 1991/92.

Table 1. Mean, range and coefficient of variability (CV) for 12 characters measured on 17 barley genotypes, Adet.

Character	Mean	Range	CV (%)
Vegetative period (days)	70	62–88**	4.74
Grain-filling period (days)	39	29–46**	11.84
Days to maturity	109	101–119*	4.30
Plant height (cm)	63.5	46–71**	7.30
Peduncle length (cm)	3.8	1–6**	32.06
Spike length (cm)	8.6	7–10**	9.11
No. grains/spike	23.6	19–40**	9.55
Grain wt/spike (g)	1.1	0.92–1.83**	8.96
No. spikes/m^2	123.3	46–185**	25.16
No. grains/m^2	2744	1113–3585**	21.01
1000-grain wt (g)	48.1	37–54.5**	1.16
Grain yield (q/ha)†	13.2	6.1–17.8**	21.28

† q = quintal, 1 q = 100 kg.
*, ** significant at the 5 and 1% level, respectively.

Grain yield was negatively correlated with vegetative period and days to maturity (Table 2). This was similar to the findings of Hadjichristodoulou (1987) for yield and vegetative period, and Samarrai et al. (1987) for yield and days to maturity. There was no correlation between yield and grain-filling period, and this was in agreement with the findings of Metzger et al. (1984) in spring barley and Samarrai et al. (1987) in barley adapted to semiarid climates.

A highly significant positive correlation was obtained between grain yield and plant height (Table 2). Similar results were reported by Gamma (1990), Hadjichristodoulou (1987), Samarrai et al. (1987) and Ceccarelli et al. (1991) for barley grown under low-moisture environments.

There was strong positive correlation between grain yield and peduncle length. The correlation coefficient between grain yield and spike length was also positive, but extremely low. Grains/spike and grain weight/spike were negatively correlated with spike length. This indicates that in this study it was the number of rows of spikes which affected the number and weight of grains/spike rather than the length of the spikes. Six-rowed genotypes tended to have more grains and larger grain weight/spike.

Grain yield was not correlated with grains/spike or grain weight/spike. Gamma (1990) obtained positive and strong correlation between grain yield and grain weight/spike. The correlations of grain yield with spikes/m^2 and grains/m^2 were strong and positive. The correlation between grain yield and kernel weight, although positive, was not significant.

In conclusion, early and tall genotypes with long peduncles and many productive spike/m^2 were associated with high grain yield under residual moisture in the present study. The results of this study can be used as preliminary information in future studies to establish optimum agronomic traits to be used in selection programs under residual moisture in the country.

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Table 2. Correlation coefficient among 12 characters measured on 17 barley genotypes grown under residual moisture.

	GP	DM	PH	PL	SL	G/S	GW/S	S/m^2	G/m^2	TKW	Grain yield
Vegetative period	-0.782***	0.742***	-0.512*	-0.625**	-0.462**	0.654**	0.656**	-0.765***	-0.614**	-0.188	-0.629**
Grain-filling period (GP)		-0.399	0.383	0.475	0.207	-0.420	-0.359	0.483	0.399	0.216	0.428
Days to maturity (DM)			-0.585*	-0.711**	-0.258	0.295	0.235	-0.684**	-0.752***	-0.072	-0.732**
Plant height (PH)				0.850***	0.279	-0.447	-0.237	0.573*	0.546*	0.558*	0.655**
Peduncle length (PL)					0.094	-0.307	-0.197	0.650**	0.716**	0.264	0.752***
Spike length (SL)						-0.607**	-0.507*	0.184	-0.022	0.440	0.076
No. grains/spike (G/S)							0.925***	-0.636**	-0.226	-0.617**	-0.345
Grain wt/spike (GW/S)								-0.612**	-0.193	-0.296	-0.240
No. spikes/m^2 (S/m^2)									0.877***	0.268	0.901***
No. grains/m^2 (G/m^2)										0.046	0.971***
1000-kernel wt (TKW)											0.275

*, **, *** significant at the 5, 1 and 0.1% level, respectively.

Branching in Tetraploid Portuguese Wheat

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Branching of spikes occurs spontaneously in some species of the genus *Triticum*. As reported by Percival (1921), who described some branching types of *T. diccocum* and *T. turgidum*, the first type of branching wheat, *Triticum ramosum*, was noticed by Plinio. The most known cultivar of branching wheat is the miracle wheat. This tetraploid wheat has attracted the attention of wheat breeders because it possesses beautiful and large spikes.

In Portugal, Vasconcelos (1933), based on Kornicke's classification and on modifications introduced by Percival's studies, created dicothomic keys and classified numerous cultivars of Portuguese wheat. From these cultivars, he described the cultivar 'Caxudo' of *T. turgidum* var. *pseudo cervinum* Korn that has branching spikes. This cultivar is a tetraploid and was collected in different regions of Portugal (Pinhel, Peneda, Alvaiazere, Elvas, Mértola and Castro Verde).

The spikes of Caxudo possess great variability in their branching character, which indicates that this character is highly influenced by climatic conditions. In our studies, we observed that if severe drought occurred during spikelet differentiation, it largely suppressed branching.

The upper part of a branching spike of Caxudo is like that of a simple spike. The branchlets usually develop at the third rachis node. In this part of the spike, the rachilla of some spikelets developed like secondary rachis with numerous spikelets, from which the secondary branchlets originated. The branched spikes have a variable number of branches.

The number of kernels per spike is an important yield component. Branching types have more grains per spike than normal ones. Therefore, to increase yield production, we crossed Caxudo with some durum wheat cultivars with good agronomic characteristics to transfer branching genes to these cultivars. F_1 was normal, i.e., unbranched spikes were dominant. F_2 progenies segregated to branching and unbranching types, but the frequency of plants with branching spikes was low (Table 1).

Table 1. Percentage of plants with branching spikes in F_2 progenies of tetraploid wheat hybrids.

Hybrid	% plants with branching spikes in F_2 generation
Hélvio × Caxudo	24.72
Cocorit × Caxudo	36.05
Caxudo × Gigantil	33.40
Gigantil × Caxudo	36.38

Our observations are in disagreement with those of Belay and Tesemma (1991) who observed no segregation when crossing branching and unbranching wheats.

Koric (1978) noticed that in hexaploid wheat, branching genes were suppressed by an inhibitor, but productivity of simple spikes was increased by increasing the numbers of spikelets per spike and kernels per spike or 1000-kernel weight.

Based on this information, we selected plants with branching and unbranching spikes. The unbranched spikes were longer and produced more grains per spike than the simple spikes (Romano 1994). Currently, we are studying these branching and unbranching wheats to select lines with increased grain productivity.

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Evaluation of Bread-Wheat Genotypes under Semiarid Tropical Conditions of Northern Sudan

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Bread wheat (*Triticum aestivum* L. subsp. *aestivum*) is a temperate crop. Its yield in hot environments has been reduced due to the acceleration of all plant developmental phases (Midmore et al. 1984). Wheat is grown in the northern, central and eastern states of Sudan, with higher yields obtained in the northern states due to the relatively longer and cooler winter season (Gorashi 1988; Ishag and Ageeb 1991; Mohamed Ali 1987).

Fifteen bread-wheat and one durum-wheat genotypes retained from CIMMYT/ICARDA nurseries were evaluated for grain yield and related characters in the 1990/91–1993/94 seasons at Dongola (19°N, 31°E), Hudeiba (17°N, 34°E) and Shendi (16°N, 33°E) in northern Sudan. A randomized complete block design with four replications was used, together with a plot size of 6 × 3 m, with a net harvested area of 10 m^2. Planting was by hand-drilling the seeds in rows 30 cm apart on flat plots, with a seed rate of 120 kg/ha. Sowing was around mid-November in all seasons and locations. The crop was irrigated at two-week intervals till maturity. Nitrogen was applied as urea in two equal doses on the second irrigation and at the heading stage at the rate of 86 kg N/ha. Weed control was by hand-weeding. Aphids were controlled by spraying with Ekatin. The characters studied were days to heading, days to maturity, plant height, grain yield and yield components.

The genotypes showed significant differences in grain yield in all seasons and locations. At Hudeiba, the best genotype over seasons in grain yield was El Neilain followed by Sham-4 and Sham-6, with yield advantages of 20, 14 and 11%, respectively, over the check, Wadi Enil (Table 1). At Shendi, the best genotype in grain yield over seasons was Sham-6 followed by Veery, with yield advantages of 10 and 6%, respectively, over the check. Although none of the genotypes outyielded the check at Dongola, the durum-wheat genotype Sham-1 was comparable. Considering average grain yield over seasons and locations, the best line was El Neilain with a slight advantage over Wadi Enil. El Neilain was released for cultivation in central Sudan, and is now showing wide adaptation in northern Sudan.

Table 1. Mean grain yield (kg/ha) of wheat genotypes in the 1990–94 seasons.

Genotype	Dongola	Hudeiba	Shendi	Mean
Sham-6	3190	3802	3215	3402
Bow'S'	3587	3538	2690	3272
Vee'S'/snb'S'	3309	3013	2856	3059
RSK/.../An64	3478	3077	2615	3057
55-1744/.../Crow'S'	3331	3264	2744	3113
HD 2206/Hork'S'	3622	3573	3065	3421
Sham-4	3260	3908	3049	3406
Veery	3883	3613	3143	3546
El Neilain	4104	4058	3058	3740
Sham-1 (durum wheat)	4540	3426	2855	3607
TL/.../Bol'S'	3535	3322	2531	3129
Buo'S'/FLK'S'	3271	3260	2998	3176
Genaro	3773	3262	3139	3391
Condor	4144	3796	2801	3580
Debeira	4280	3500	3058	3613
Wadi Enil (check)	4673	3423	2945	3680
Mean	3723	3490	2952	
SE (±)	336	252	231	
CV (%)	15	12	15	
Significance level	**	**	**	

** significantly different at $P = 0.01$.

Grain yield related characters were studied at Hudeiba with significant differences among the genotypes in all characters (Table 2). Most of the lines were of medium maturity, taking around 60 days to heading and 100 days to maturity, which indicates good adaptation to northern Sudan conditions where the winter season is relatively longer. The best genotypes in tillering were Sham-6, HD 2206/Hork'S', Sham-4 and Condor, with more than 700 fertile spikes/m^2. El Neilain was comparable to Wadi Enil and Debeira, with more than 600 fertile spikes/m^2. The genotype TL/.../Bol'S' and the durum-wheat genotype Sham-1 were the highest in kernel weight (49–50 g/1000 seeds). Generally, there were some compensatory effects in the yield components of these genotypes.

The results of this evaluation showed that the promising genotypes El Neilain, Sham-6, Sham-4 and Sham-1 could be considered for cultivation by farmers in northern Sudan.

Table 2. Performance of wheat genotypes in yield-related characters at Hudeiba.

Genotype	Days to heading	Days to maturity	Plant height (cm)	No. spikes/m²	No. seeds/spike	1000-seed weight (g)
Sham-6	62	104	77	803	36	40
Bow'S'	96	104	80	513	52	39
Vee'S'/snb'S'	70	105	78	563	44	43
RSK/.../An64	71	106	81	570	50	40
55-1744/.../Crow'S'	58	102	80	627	42	45
HD 2206/Hork'S'	68	104	89	727	46	37
Sham-4	60	104	76	717	38	40
Veery	62	102	80	493	47	45
El Neilain	59	107	90	647	42	43
Sham-1 (durum wheat)	56	100	71	550	47	49
TL/.../Bol'S'	61	102	91	550	44	50
Buo'S'/FLK'S'	64	104	82	580	48	44
Genaro	58	99	76	533	40	46
Condor	59	103	78	713	39	41
Debeira	69	105	88	607	43	46
Wadi Enil (check)	61	106	84	633	41	45
Mean	63	104	81	614	44	44
SE (±)	1	1	2	33	2	2
CV (%)	4	2	5	3	10	7
Significance level	**	**	**	**	**	**

** significantly different at $P = 0.01$.

Acknowledgements

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Resistance to Loose Smut and Rust in Wheat

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Wheats (*Triticum* spp.) constitute an important source of food for the growing populations of developing countries. The main problem in stabilizing wheat production is genetic vulnerability to important diseases such as rusts, loose smut and karnal bunt (Swaminathan 1974). Large areas of northwestern India—Punjab, Haryana, Uttar Pradesh, Bihar, parts of Rajasthan and Madhya Pradesh—are under wheat cultivation. In these areas, leaf rust (*Puccinia recondita* Rob. ex Desm. f.sp. *tritici* Eriks.), stripe rust (*P. striiformis* West. f.sp. *tritici*), loose smut (*Ustilago tritici* (Pers.) Rostr.) and karnal bunt (*Tilletia indica* Mitra) are the major diseases. Therefore, varieties having combined or multiple disease resistance are preferred. However, the most popular and dominant cultivars, such as HD2329, HD2285 and WH147, are generally susceptible to leaf rust and loose smut. Attempts have been made to locate multiple resistance against loose smut and rusts in India (Aujla et al. 1990). A large number of wheat lines was evaluated under artificial epiphytotic conditions against loose smut and leaf and stripe rusts to find sources of resistance.

Five hundred and thirty-nine wheat lines were sown in 1-m rows, 25 cm apart in the field at the Indian Agricultural Research Institute, New Delhi, during 1987/88, 1988/89 and 1989/90. For screening against loose smut, five spikes of each line were inoculated at mid-anthesis with a local strain of the loose smut pathogen using a hypodermic syringe. The inoculated spikes were covered with paper bags and clipped to maintain high humidity for successful infection. The wheat lines were tested for three years to confirm the resistance. The incidence of the disease was recorded at ear emergence on a single-plant basis. The lines consistently free from loose smut infection were considered resistant.

The entries resistant to loose smut were tested against leaf rust and stripe rust pathogens during 1990/91 and 1991/92. For rust inoculation, the entries were sown in 1-m rows and surrounded by infector rows of susceptible wheat varieties such as Agra local, Kharchia, Sonalika and Kalyansona, which were separately inoculated with urediospore suspensions of leaf and stripe rust. Rust intensities were recorded using the scale of Peterson et al. (1948).

Table 1 shows the incidence of loose smut and rust reaction of the entries. Twenty-eight entries were free from loose smut infection after three years of evaluation. Stripe rust occurred in traces in some of the entries which showed resistant reaction. Infection by leaf rust was also low. These wheat lines, besides possessing resistance, are also agronomically promising; hence, they could be exploited as resistant donors for breeding cultivars resistant to these pathogens.

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Table 1. Wheat entries showing rust reaction and loose smut incidence.

Entry	Leaf rust		Stripe rust		Loose smut
	1990/91	1991/92	1990/91	1991/92	
DL-896-2	0	0	TR	TR	R
H. 377-11-2	0	0	0	TR	R
H. 709-23-2-5	0	0	0	0	R
H. 798-94-1	0	0	0	0	R
H. 802-65-7	TR	0	0	0	R
IC. 47481	TR	TR	0	0	R
IC. 47585	TR	0	0	0	R
IC. 47791	TR	0	0	0	R
IC. 49437	TR	TR	0	TR	R
HD 4571	5R	TR	5R	TR	R
WDL-9	TMR	TR	20R	5R	R
Bob-white	0	TR	0	TR	R
CINC "S"	0	0	TR	0	R
FG'S'GGO-Vz380*515*Cr'S'	TS	TS	TMR	TR	R
MG-42	TS	TR	0	TR	R
MG-231-19	TS	TR	0	0	R
HD-29	0	TR	0	0	R
ISD 75-3-1	TS	0	0	0	R
ISWRN-306	TS	0	0	0	R
ISWRN-29	TR	0	5R	TR	R
Raj 2296	TR	0	0	TR	R
UP 2124	0	TR	0	0	R
ISWRN-338	TR	TR	0	0	R
USDA-139	TR	TR	0	0	R
DACK'S'/RTTE-LDS-YAV'S'	0	0	0	0	R
Macs-1967	0	0	TR	0	R

0 = no infection; TR = trace infection; R = resistant; TMR = trace, moderately resistant; TS = trace susceptible.

Outbreaks of Tef Epilachna (*Epilachna similis*) in Wheat in the Central Rift Valley of Ethiopia

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The Nazret area of Ethiopia is a semiarid area in the Rift Valley at an altitude of 1400–1600 m asl, with low and erratic rainfall (about 600–800 mm per year), most of which falls between April and October. Traditionally, Nazret area is known for its production of maize and beans (Mulatu and Regasa 1987). During the past couple of years, wheat (*Triticum aestivum* L. subsp. *aestivum*) production has been increasingly popular in warm areas of the Rift Valley. Because of the unreliable rains prevalent in Nazret area, there has been a shift from maize production to tef (*Eragrostis tef* Zucc. (Trotter)) and wheat. With the increase in wheat production in these areas, the damaging tef epilachna (*Epilachna similis*) has emerged, forcing many farmers to quit wheat production.

A survey was carried out both in Nazret Research Center's wheat field and in farmers' wheat fields in other areas such as Nazret, Dera, Meki and Zewai, all of which lie in the rift system, to assess the extent of damage caused by *Epilachna similis*. A more detailed study, however, was carried out at the Center's wheat field (commercial variety Pavon-76) in August 1992. Groups of tillers were selected at random at different spots of the wheat field. Each of these groups of tillers was considered as plots or treatments. We recorded the number of tillers, tillers with scarified leaves, number of tef epilachna (larvae, pupae and adults) and leaf scarification score (1–9 scale, where 1 = no scarification, 9 = complete damage). From the wheat field, 138 pupae were collected and each was placed in a plastic capsule to observe the possibility of pupal parasitism.

Damage Assessment

The infestation was uniform; most of the fields suffered the same degree of attack. The wheat field at the flag-leaf stage looked like grey straw due to heavy scarification. The larvae and adult beetles were observed feeding and moving around. The larvae and adults cause almost the same damage; they usually feed on the lower surface of the leaves and leave the epidermis of the upper surface untouched. Heavily attacked leaves are skeletonized, shrivelled and dried up. Young plants are seriously checked in growth, and yield of older plants is reduced. On average, leaf scarification score was 4.3 ± 1.4 (range = 2–6). Percent tillers with scarified leaves ranged from 50 to 100 with an average of 96.2 ± 11.3. Up to four epilachna were recorded per tiller with an average of 0.7 ± 0.4.

Parasitoids

The first Hymenopteran parasitoid emerged 12 days after collection of the pupae. Out of a total of 138 pupae, 10 were parasitized. Multiparasitism was also noted as there were 8.2 ± 2.1 (range = 6–12) parasitoids per pupa.

It is true that tef epilachna is getting more and more important and is becoming a limiting factor with wheat cultivation increasing in the Rift Valley. More studies should be undertaken on this insect so that proper control methods could be proposed.

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Response of Wheat Genotypes to *Azotobacter* Inoculation under Rainfed Conditions

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About 27% of the total area under wheat (*Triticum aestivum* L. subsp. *aestivum*) cultivation in India is rainfed, where the crop grows largely on conserved soil moisture from preceding Monsoon rains. Water deficit, poor soil fertility, low use of inorganic fertilizers, poor organic carbon and very poor rhizospheric activity in predominantly light-textured soils are major factors for low wheat production in such areas (Behl et al. 1992). *Azotobacter chroococcum*, a free-living dizotroph, produces growth regulators and antifungal substances, fixes nitrogen, and produces siderophores (Suneja and Lakshminarayana 1993) and ammonia (Narula and Yadav 1989). Availability of wheat varieties possessing appropriate phenology, adaptive to water-deficit conditions and responsive to *Azotobacter* inoculation would be worthwhile.

Ten spring-wheat genotypes were evaluated over two years for their response to *Azotobacter* inoculation under water-deficit rainfed conditions. Clean seeds (100 g) of the genotypes were inoculated with ammonia-excreting analogue resistant spontaneous mutant Mac 27 of *Azotobacter chroococcum*. To accomplish this, a culture broth of Mac 27 was mixed with charcoal carrier. A concentrated sucrose solution (50%) was used as adhesive so that the bacterial culture should stick to the seeds. Inoculated as well as uninoculated (control) seeds of these genotypes were sown in plots with five 3-m-long rows in a randomized block design (sandy loam, organic carbon 0.21%, 350 mm annual rainfall and field capacity 15–16%). The plant-to-plant and row distances were 10 and 25 cm, respectively.

Observations on 10 plants in each plot were recorded on plant height, number of tillers per plant and spikelets per spike, 100-grain weight and biological and grain yields per plant. Mean data on these traits were subjected to analysis of variance which revealed significant differences among genotypes and treatments. Significant genotype by *Azotobacter* interaction suggested that some genotypes responded to the bacterium more than others. Only five genotypes recorded satisfactory grain yield, hence their data is presented here (Table 1). Genotype WH533 significantly outyielded all the other genotypes. However, the control and *Azotobacter* treatment were similar. On the other hand, the heat-tolerant mutant WH147M (Behl et al. 1986) and the drought-tolerant genotype HI1011 were equivalent both in the control and treated plots for grain yield and yield components, but they showed significant responses to *Azotobacter* inoculation compared with their respective controls.

The genotypes, on average, manifested about 18% response in grain yield and spikelets per spike. Likewise, WH147M and HI1011 showed about 9 and 17% response, respectively, in tillers per plant. Variety C306 had the maximum response to *Azotobacter* inoculation in tillers per plant, while PBW175 revealed the maximum response in biological yield.

Colonization of *Azotobacter* in the rhizosphere depends on the exudation of organic compounds which serve as a carbon source for growth and multiplication of bacterium (Martine-Toledo et al. 1988). In a previous study, it was found that WH147M and HI1011 exude carbon at least twofold more than WH147 (Behl et al. 1993). Moreover, WH147M has an extensive root system, both in terms of root hair number and root length.

In addition to nitrogen fixation, *Azotobacter* is also known to produce growth-promoting phytohormones, such as GA, and IAA (Pathak and Narula, personal communication). These phytohormones may be the reason for the significantly larger plant height in *Azotobacter*-treated WH147M and HI011. Maximum grain yield in WH147M could be realized in the early spring (October) as this genotype requires higher photo-thermo units to flower by mid-February when the temperature for grain development is most optimal (Behl et al. 1986). In that case, high-temperature-tolerant strains of *Azotobacter* are required to harness the favorable genotype × bacterium interaction for enhanced wheat production under rainfed/dryland conditions. The mutant strains of *Azotobacter* which can tolerate 43–45 °C temperature have been developed at CCS Haryana Agricultural University in Hisar and must be evaluated under field conditions using WH147M as a host.

The results of this evaluation suggest that the favorable host by bacterium interaction could be exploited to enhance production of rainfed wheat.

Table 1. Mean performance of five wheat genotypes with (A) or without Azotobacter inoculation (C) under rainfed field conditions.

Genotype	Character					
	Tillers/ plant	Plant height (cm)	Spikelets/ spike	Biological yield/ plant (g)	Grain yield/ plant (g)	100-grain weight (g)
WH147M						
C	10.6	82.5	20.6	45.3	16.0	4.26
A	11.6	85.3	24.3	48.4	19.0	4.33
% increase	9.43	3.39	17.96	6.84	18.75	1.64
WH533						
C	11.0	80.0	19.3	52.6	26.3	4.70
A	12.0	81.3	20.3	53.6	25.8	4.70
% increase	9.09	1.62	5.18	1.90	–	–
PBW175						
C	9.0	90.6	17.3	23.6	10.3	5.06
A	10.0	91.6	21.0	28.3	12.6	5.10
% increase	11.11	1.10	21.38	19.9	22.33	0.79
HI1011						
C	13.0	90.6	17.6	43.0	16.3	5.26
A	15.3	90.0	21.6	42.3	19.6	5.33
% increase	17.69		22.72	–	20.24	1.33
C306						
C	14.3	109.0	19.6	21.6	10.3	5.3
A	17.0	109.3	21.0	24.0	11.0	5.43
% increase	18.88	0.27	7.14	11.11	6.79	2.45
CV (%)	1.4	3.1	2.1	4.2	2.5	0.12

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Cereal News

Forthcoming Events

1999

American Meteorological Society Annual Meeting, **Wyndham Anatole Hotel, Dallas, USA, 10–15 January**; contact: Richard Hallgren, 617/227-2425.

Western Plant Growth Regulator Society Annual Meeting, **Hilton Hotel, Anaheim, CA, USA, 13–14 January**; e-mail: *wgraves431@aol.com*.

California Plant and Soil Conference, **Holiday Inn Plaza Park,Visalia, USA, 20–21 January**; contact: Shannon Mueller, 209/456-7261.

Joint Meeting of Society for Range Management and American Forage and Grassland Council, **Omaha, NE, USA, 21–26 February**; contact: Dana Tucker, 800/944-2342.

North American International Erosion Control Association Conference, **Nashville, TN, USA, 22–26 February**; e-mail: *ecinfo@ieca.org*.

Workshop on Farmers and Scientists in a Changing Environment: Assessing the Impact of Research in West Africa, **Cotonou, Benin, 22–26 February**; e-mail: *course79@uni.hohenheim.de*.

Biowork II: International Workshop on Plant Breeding in the Turn of the Millennium, **Viçosa, Minas Gerais, Brazil, 2 March**; *www.ufv.br/dft/biowork/index.htm*.

Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balances, **San Luis Obispo, CA, USA, 10–13 March**; e-mail: *stephens@uscid.org*.

International Symposium on Expanding the Horizons for Soil, Plant and Water Analysis, **Brisbane, Queensland, Australia, 22-26 March**; +61 2 6257 3299.

European Symposium on Industrial Crops and Products, **Bonn, Germany, 23–25 March**; e-mail: *bluezulu@dial.pipex.com*.

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

International Symposium on the Nutrition of Herbivores, **San Antonio, TX, USA, 11–16 April**; e-mail: *w-ellis@tamu.edu*.

International Erosion Control Association Asia-Pacific Conference, **EDSA Plaza Hotel, Manila, Philippines, 19–21 April**; e-mail: *pcoc@manila-online.net*.

International Herbage Seed Conference, **Istituto di Miglioramento Genetico Vegetale, Università degli Studi di Perugia, Italy, 23–27 May**; e-mail: *imgv@unipg.it*.

International Meeting on Soils with Mediterranean Climate, **Barcelona, Spain, 4–9 July**; e-mail: *jabechbo@porthos.bio.ub.es*.

Enzymes in the Environment: Activity, Ecology and Applications, **Granada, Spain, 12–15 July**; *http://www.orst.edu/granada/*.

XVI International Botanical Congress, **Saint Louis, Missouri, USA, 1–7 August**; 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*.

Global Soy Forum, **Sheraton Towers, Chicago, USA, 4–7 August**; *http://www.gsf99.uiuc.edu*.

AIC Annual Meeting, **Charlottetown, Prince Edward Island, 8–10 August**; *www.upei.ca/~aic99*.

Conference on Food and Forestry: Global Change and Global challenges, **University of Reading, UK, 20–23 September**; e-mail: *sm.wilkinson@elsevier.co.uk*.

Conference on Desert Technology: Deserts in Changing Climates, **Sparks, NV, USA, 3–8 October**; *http://www.engfind.org*.

National Small Farm Conference, **Regal Riverfront Hotel, St. Louis, MO, USA, 12–15 October**; contact: Troy Darden, 573/681-5587.

Seminar on Concepts for Modernization of Irrigation Water Delivery Systems and Workshop on Modernization of Irrigation Water Delivery Systems, **Phoenix, AZ, 17–21 October**; e-mail: *stephens@uscid.org*.

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