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Participatory Barley Breeding for Improving Production in Stress Environments

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ABSTRACT

Farmer participation is a new approach to barley breeding in Jordan, besides the conventional barley-breeding program. One cycle of decentralized participatory selection was conducted in eight locations in Jordan. These were: Khanasri, Ramtha East, Ramtha West, Ghweir (Station), Ghwair (Field), Rabba, Muaqure and Mohay. A set of 200 barley entries was planted during November 19-26/2002 in seven host farmers' fields and in one Research station. These entries included fixed lines and segregating populations, in addition to two checks; one improved six-row released variety "Rum", and a local check unreplicated in one research station and in the seven fields of host farmers. In each location, the plots were arranged in Incomplete Blocks Design of ten plots each, and the layout was ten rows and twenty columns. This allowed both an Incomplete Block Design analysis as well as a bi-dimensional spatial analysis. The local check yielded more than the improved variety Rum in 5 locations, but less in 2 locations. However, the differences were not significant. In four of six villages there were several lines outyielding the local check. There were large entries x locations interaction effects that were more than four times larger than entries effect. This confirms that the classification of entries varies greatly with the location. There were large differences between the correlation coefficients both between locations and within locations. Both breeders and the farmers generally selected for taller plants. However, in Ghwair there was no relation between the farmer's or the breeder's score and plant height, while in Rabba the breeders selected tall plants and the farmers selected short plants. The correlation coefficients between the breeder's scores and grain yield and biological yield were not always significant, and were often lower than those relative to the farmer's scores. Kernel weight was much more important as selection criterion for the farmer than for the breeder, and more important than spike length, which was strongly correlated with farmer's score in Mohai and Ramtha. Eventually, the correlation coefficients between farmer's and breeder's scores varied from highly positive and significant, such as in Khanasri, Mohai, and Ramtha, to non significant such as in Gwheer and Rabba. During this first cycle of selection, farmers show a modest preference for two row types, which increased their frequency from 70.7% in original population to 74% among the selected entries, and a strong preference for white-seeded types which increased from about 66% to 83%, while the frequency of the black seeded types was reduced in half.

KEYWORDS: barley, *Hordeum vulgare*, genotype by environment interaction, farmer participation, participatory plant breeding.

INTRODUCTION

Barley (*Horduem vulgare* L) is a widely adapted and important cereal crop. In the dry areas, it grows under low soil fertility levels and moisture stress conditions where wheat performs poorly or fails to survive. During the period 1990 to 2003, the average harvested area of barley in Jordan was 57 thousand ha. The average productivity was about 880kg/ha, while the average productivity in major regions of the world was about 2650 kg/ha. Therefore, research is needed to increase the productivity of barley per unit area in Jordan. Improving agricultural practices and the genetic make-up of plants

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could increase this productivity (Shakhatreh *et al*., 2001).

Participatory Crop Improvement (PCI) stated in the past decade as an alternative plant breeding approach for developing countries in response to the recognition that conventional breeding of the formal sector institutions (Formal Crop Improvement, FCI) had brought little significant crop improvement to Resource–poor farmers in marginal and harsh environment (Almekinders and Elings, 2001; Ceccarelli *et al*., 2000). The main reason for this, is the fact that formal plant breeding in developing countries is conducted in favorable high-input environments (Ceccarelli and Grando, 1991; Shakhatreh *et al*., 2001). Farmers' participation in the technology development as well as in plant breeding is neither new nor revolutionary. Many years ago women and men have been molding the phenotype of hundreds of plant species (Duvic, 1996).

Participatory Varietals Selection (PVS), defined as farmer can make their choices among final or nearly final stages of crop improvement program, a process now becoming more important in international crop improvement program (Witcome *et al*., 1999), on the other hand, Participatory Plant Breeding (PPB) shears the responsibility of selection with the end users at early stages (when the amount of genetic variability is at the maximum) (Ceccarelli *et al*., 2000).

Low-rainfall areas of Jordan are characterized by a high variation from year to year. Therefore, almost half of the area where barley is grown is a high-risk area where crop failures are common and they affect resource-poor farmers who have little or no other options. Consequently, the development of barley genotypes that have greater ability to produce substantially higher yield in the presence of drought stress is the most economic solution.

This paper compares farmer’s and breeder’s selection on farmer fields using a considerable number of genotypes within a range of environments, most of which are stressful and unfavorable for high yields.

Materials and Methods

The Target Areas

The research area is the north, central and south part of Jordan, which receives between 350mm (in Rabba) and 150mm (in Mohai) of rain. The characteristics of the locations are: Mohai: 45km south east of the Al-Karak province, with an average annual rainfall of (130-150mm). Rabba: 130km south of Amman, with an average annual rainfall of (340mm). Ghweer: 150 km south of Amman, with an average of rainfall of (280mm). Muwaqar: 50km south east of Amman, in the arid areas, with an average annual rainfall of (150mm). Ramtha: 100km north of Amman, with an average of annual rainfall of (225mm).

The Breeding Material and Experimental Design

Two hundred entries (both segregating populations and fixed lines) were planted at each of the farmer’s field (host farmers) and in the research station (Ghweir station) in November 19, 2001. The seeds tested in this study were provided by ICARDA. The entries included 179 test genotypes and two checks (Rum and the local check). The local check was a landrace and the host farmers supplied its seed. In each trial, Rum was repeated 11 times and the local check 10. However, while Rum was repeated in all locations, the local check varied with the locations. Plot size was 10m^2 (8rows X 0.25m apart X 5m long). The trials were unreplicated with a different randomization at each location, except East and West Ramtha. The 200 plots were arranged in incomplete blocks of ten plots each, and the layout was ten rows and twenty columns. This allowed both an incomplete block analysis as well as a bi-dimensional analysis. In each trial, the scientists recorded the following data: plant height (ph) in cm, spike length (sp) in cm, grain yield (gyld), total biomass (byld) and straw yield (syld), all in kg/ha, harvest index (hi) as ratio gyld/byld, and 1000 kernel weight (kw) in g. The data were subjected to different types of analysis. Firstly, the data were analyzed with a GENSTAT program for spatial analysis of un-replicated trials in which the response of the checks provides the basis for modeling the spatial variability in the field and to adjust the genotypes' performance. The efficiency of the various spatial models is compared against the completely randomized design. For each variable, nine models are fitted (Table1); the selection of the best model is based on comparing Akaike Information Criterion (AIC) values in terms of deviance of the model. The model selection is done assuming the genotype effects as fixed. In this case, we compute the BLUEs (Best Line Unbiased Estimated) of the genotype effects. For the selected model, the genotypes are then assumed as random effects, and the BLUPs (Best Line Unbiased Predicted) and heritability are computed. In Table (1), AR stands for first order auto-regressive error in column number (i.e. along rows) and ARAR for first order auto-regressive errors in column number and in row number; L stands for the fixed linear trend fitted in column number. The Wald test was used to test statistical significance of the linear trend in column number. Where linear trend was not significant at 5% level, the best of the models 1-3 was selected; otherwise, the best of models 4-9 was selected.

The BLUPs, which are the genotypic values to be used for selection, were then used to calculate the correlation coefficients (r) between traits at the same location, as well as between grain yields across different locations. Because a different randomization was used at each location, there are actually estimates of genetic correlation coefficients. Eventually, the BLUPs for grain yield were used to calculate genotype by environments interaction using a combination of clustering and ordination procedures that consist in clustering both genotypes and environments into groups, two-way analysis of variance, the calculation of the percentage between genotype group × between environment group sums of squares retained for different grouping levels, and eventually using biplots to represent the information contained in G × E tables in a two or three dimensional graph. The interpretation of the biplot is given by Kroonenberg (1995). This analysis was done using the software package GEBEI (Watson *et al*., 1996) on the environment-standardized BLUPs.

Results and Discussion

The total amount of rainfall varied from 276 mm in Rabba to 115 mm in Muwaqar (Figure 1). Because of the limited rainfall there was no grain yield in Khanasri. In Muwaqar the effects of the low rainfall were made worse by the soil characteristics (fine silty, mixed, thermic, typic calciorthid). Generally, this location is characterized by weak vegetative cover, soil surface of high silt content, strong surface crust, low organic matter and weak aggregate stability. The combination of poor soil and low rainfall caused very poor establishment and the trial was discontinued. Also, the low rainfall in Khanasri caused crop failure. So, only plant height and biomass yields were measured.

Means of yield were generally low, ranging from about 69 kg/ha in Ramtha East to about 913 kg/ha in Rabba, where the crop suffered from late drought conditions (Table 2). The intensity of the drought stress, which affected the crop, is also indicated by the low harvest index, (less than 0.3), short plant height and the small kernels. The local check (i.e. the local landrace) yielded higher than the improved variety Rum in 5 locations, but less in the two locations, Mohai and Ramtha East with the lowest grain yield (Table 3). However, the differences were not significant. In four of the six villages there were several lines outyielding the local check, and in those locations where Rum outyielded the local check, there were several lines out yielding the best check. The heritability of grain yield was very low in Ramtha West and low in Ghweer; similarly, the heritability of biomass yield was very low in Khanasri. The genetic correlations between grain yield measured in different locations (Table 4) were not significant, except the one between the research station and the Farmer's field at Ghweer location.

There were large entries x locations interaction effects (Table 5). They were more than four folds larger than that of the entries effects. This confirms that the classification of entries varies greatly with the location, as already suggested by the correlation coefficients. There were large differences between the correlation coefficients both between locations and within locations (Table 6). Both the breeders and the farmers generally selected for taller plants. However, in Ghweer there was no relation between the farmers' or the breeders' score for the plant height, while in Rabba the breeders selected tall plants and the farmers selected for short plants. Farmers' scores were always significantly correlated with both grain yield and biomass yield, with the only exception of biomass yield in Mohai. The correlation coefficients between the breeders' scores and grain yield and biological yield were not always significant, and were often lower than those related to the farmers' scores. The correlation coefficients with straw yield were similar to those with biomass yield. Kernel weight was much more important as selection criterion for the farmers than for the breeder, and more important than spike length, which was strongly correlated with farmers' scores in Mohai and Ramtha. Eventually, the correlation coefficients between farmers' and breeders' scores varied from highly positive and significant, such as in Khanasri, Mohai and Ramtha, to non-significant such as in Ghweer and Rabba.

In conclusion, farmers were more efficient than breeders for selecting certain traits that are more desirable for them at each location. Whereas breeders were also more efficient than farmers for certain traits. Therefore, combining the knowledge of farmers and the science of breeders and allowing the farmers to express their freedom on choosing and selection of genotypes suitable for their own locations will be the first step towards the participatory plant breeding in Jordan. Eventually, there is nothing to lose with the participation of farmers in selection practices. In the contrary, benefits will be high for both the farmers and breeders.

Acknowledgement

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Table 1: List of models used to describe spatial variability and analysis.

No.	Random terms and Spatial errors(*)	Fixed linear trend	Abbreviation
1	No spatial errors (Id)	-	CrdId
2	AR	-	CrdAR
3	ARAR	-	CrdARAR
4	Id	Linear in column num. (L)	CrdLId
5	AR	Linear in column num. (L)	CrdAR
6	ARAR	Linear in column num. (L)	CrdARAR
7	Id, CS	Linear in column num. (L)	CrdLCSId
8	AR, CS	Linear in column num. (L)	CrdLCSAR
9	ARAR, CS	Linear in column num. (L)	CrdLCSARAR

(*) Id = Independent errors; CS= random cubic spline in column number.

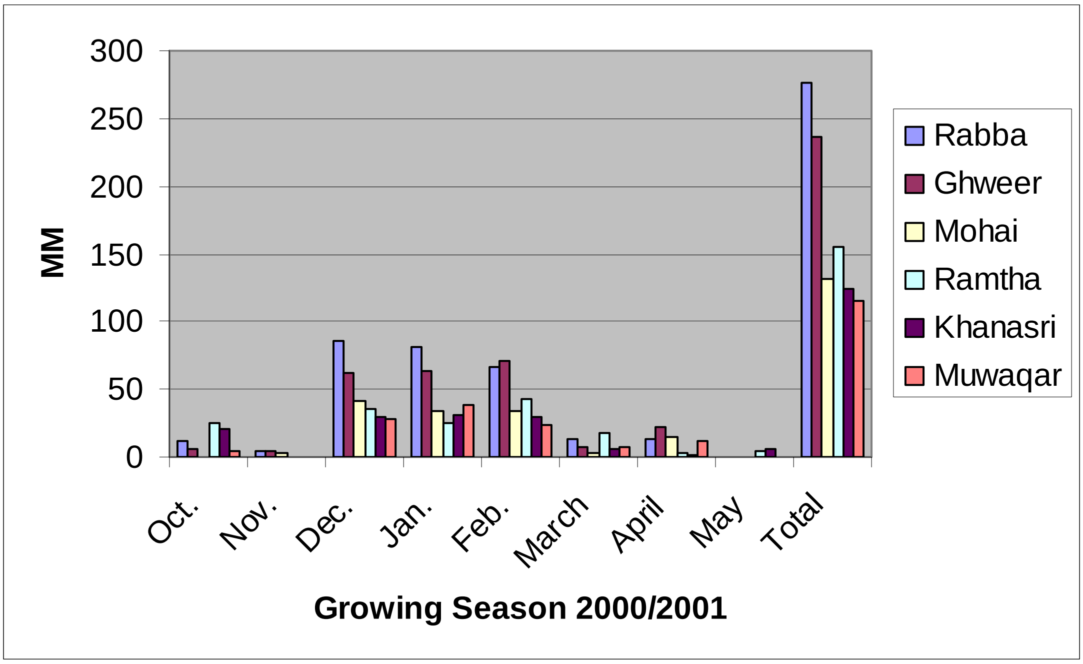

Figure 1: Annual rainfall (mm) and its monthly distribution in Rabba, Ghweer, Mohai, Ramtha, Khanasri and Muwaqar during 2000/2001 growing season.

Table 2: Mean values of plant height (ph), biomass yield (byld), grain yield (gyld), straw yield (syld), harvest index (hi), spike length (sp) and 1000 kernel weight (kw).

Trait	Ghweer	Station	Khanasri	Mohai	Rabba	RamthaE	RamthaW
ph	32.7	42.8	11.2	21.4	56.8	22.6	39.8
byld	3500	2959	287	928	3651	1287	3272
gyld	644	680	-	140	913	69	521
syld	2853	-	-	800	2734	1197	2666
hi	0.19	0.26	-	0.15	0.28	0.06	-
sp	5.9	5.9	-	4.0	5.7	-	3.0
kw	32.5	29.6	-	24.9	34.4	15.0	21.2

Table 3: Grain yield of the highest yielding entry in each location, number of entries yielding more than the best check and the local check, heritability, and mean yields of the local check and the improved released variety "Rum".

Entries	Ghweer	Ghweer St	Khanasri*	Mohai	Rabba	Ramtha E	Ramtha W
best line	784	1179	299	290	1289	435	665
Lines > best check	1	41	149	106	41	105	3
Lines > local check	1	41	149	167	41	180	3
Heritability	0.3	0.54	0.05	0.51	0.54	0.89	0.06
Checks							
Local check	781	810	283	83	989	5	647
Rum	610	735	274	126	755	27	480

***** Biomass yield**.**

Table4: Genetic correlatriona between grain yields of 181 entries grown in six locations.

	Ghwair	Ghweer St	Mohai	Rabba	Ramtha E
Ghweer St	0.338*				
Mohay	0.006	-0.038			
Rabba	-0.048	0.006	-0.009		
RamthaE	0.101	0.014	0.126	0.072	
RamthaW	0.078	0.024	-0.074	-0.029	-0.095

* Level of significance: r = ± .146 (P<0.05); r = ± .191 (P<0.01).

Table5: Analysis of variance of grain yields of 181 entries grown in six locations.

Source of Variance	d.f.	SS	MS	%
Entries	180	2166576	12036.5	2.00
Locations	5	96614576	19322915.2	89.35
E x L interaction	900	9344624	10382.9	8.64
Total	1085	108125776	99655.1	

Table6: Correlation coefficients* between the average farmers' score (fs) and the average breeders' score (bs), and the genotypic values of the 181 entries for plant height (ph) biomass yield (byld), grain yield (gyld), straw yield (syld), harvest index (hi), spike length (sp) and kernel weight (kw).

Location	F/B	ph	byld	gyld	syld	hi	sp	kw	Fs
Ghwair	fs	0.135	0.255	0.340	0.193	0.169	0.136	0.159	1.000
	bs	0.134	0.057	0.004	0.062	-0.067	-0.017	-0.089	-0.011
Station	fs	0.692	0.390	0.391	-	0.123	0.162	-0.090	1.000
	bs	0.633	0.106	0.157	-	0.112	0.069	-0.259	0.674
Khanasri	fs	0.628	0.392	-	-	-	-	-	1.000
	bs	0.592	0.320	-	-	-	-	-	0.796
Mohai	fs	0.558	0.166	0.415	0.037	0.295	0.350	0.353	1.000
	bs	0.628	0.035	0.285	-0.048	0.258	0.371	0.250	0.703
Rabba	fs	-0.538	-0.061	0.170	-0.094	0.234	-0.038	0.515	1.000
	bs	0.535	0.164	0.149	0.152	-0.088	0.016	-0.182	-0.039
Ramtha E	fs	0.497	0.552	0.721	0.523	0.408	-	0.613	1.000
	bs	0.471	0.558	0.646	0.535	0.299	-	0.464	0.746
Ramtha W	fs	0.561	0.263	0.238	0.268	-	0.497	0.604	1.000

Level of significance: r = ± .146 (P<0.05); r = ± .191 (P<0.01).

REFERENCES

Almekinders, C.J. M. and Elings, A. 2001. Collaboration of Farmers and Breeders: Participatory Crop Improvement I Perspective. *Euphytica*, 122:425-438.

Ceccarelli, S. and Grando, S. 1991. Environment of Selection and Type of Germplasm in Barley Breeding for Loe-yielding Conditions. *Euphytica*, 57: 207-219

Ceccarelli, S., Grando, S., Tutwiler, R., Baha, J., Martini, A.M., Salahich, H., Goodchild, A. and M. Michael. 2000. A Methodological Study on Participatory Barley Breeding I. Selection Phase. *Euphytica*, 111: 91-104.

Duvic, D. N. 1996. Plant Breeding, an Evolutionary Concept. *Crop Science*, 36: 539-548.

Kroonenberg, P. M. 1995. Introduction to Biplot For G x E Tables. Research Report no 51, Center for Statistics, The University of Queensland, Queensland: 22.

Shakhatreh, Y., Kafawin, O., Ceccarelli, S. and Saoub, H. 2001. Selection of Barley Lines for Drought Tolerance in Low-Rainfall Areas. *J. Agronomy and Crop Science*, 186: 119-127.

Watson, S.H., Delacy, I.H., Podlich, D.W. and Basford, K.E. 1996. GEBEI. An Analysis Package Using Agglomerative Hierarchical Classificatory and SVD Ordination Procedure for Genotype X Environment Data. Research Report No. 57. Department of Mathematics, University of Queensland, Brisbane, Australia.

Witcombe, J.R., Peters, R., Jones, S. and Joshi, A. 1999. Crop Improvement. IV. The Spread Impact of Rice Variety Identified by Participatory Varietal Selection. *Experimental Agriculture*, 35: 471-487.

تربية الشعير بالمشاركة مع المزارعين من اجل زيادة الانتاجية تحت الظروف البيئية المجهدة

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ملخـص

ان برنامج تربية الشعير في الأردن ينفذ من خلال برنامج التربية الرسمي (التقليدي)، بجانب ذلك فلقد بدا برنامج تربية الشعير في الأردن بتنفيذ منهجية جديدة هي مشاركة المزارعين في تربية الشعير وذلك من اجل رفد برنامج تربية الشعير الوطني بأصناف ذات إنتاجية عالية ومتحملة للظروف البيئية المحلية ومنتخبة من قبل المربين والمزارعين. تم تنفيذ دورة انتخاب أولى بمشاركة لامركزية في سبعة مناطق في الأردن هي: الرمثا الشرقية، الرمثا الغربية،الخناصري، الغوير (محطة زراعية)، الغوير، الربة، الموقر ومحي.استخدم (200) مدخل من الشعير في كل حقل من حقول المزارعين (المزارعين المضيفين) بالإضافة إلى المحطة الزراعية وزرعت خلال الفترة 19-2002/11/26. احتوت المدخلات على سلالات نقية وسلالات منعزلة(F3 bulk) بالإضافة إلى شاهدين هما : (رم) شاهد محسن سداسي الصفوف و(بلدي) سلالة محلية ثنائية الصفوف و زرعت باستخدام تصميم القطاعات غير الكاملة (10 صفوف) و(20) عموداً وذلك من اجل اجراء التحليل الإحصائي للقطاعات غير الكاملة (Incomplete Block) والتحليل الثنائي الأبعاد (bi-dimensional spatial analysis). دلت النتائج على تفوق السلالة المحلية (بلدي) على الصنف المحسن (رم) في خمسة مواقع، في حين تفوق الصنف المحسن (رم) على السلالة المحلية (بلدي) في موقعين فقط. الا أن هذا التفوق لم يكن معنويا.كان تأثير تداخل الصنف مع البيئة أربعة أضعاف التأثير العائد للأصناف. أظهرت النتائج فروقا عالية في معامل الارتباط ضمن وبين المواقع المختلفة. وأظهرت الدراسة توافق كل من المزارعين والمربين في انتخاب أطول النباتات، إلا أنه في موقع الربة انتخب المزارعون النباتات القصيرة في حين انتخب المربون النباتات الطويلة. كان المزارعون أكثر كفاءة من المربين في الانتخاب المتعلق في الإنتاج الحبي، الإنتاج الكلي وطول السنبلة خاصة في محي والرمثا. تراوح معامل الارتباط بين المزارعين والمربين بين إيجابي ومعنوي في كل من الخناصري، محي والرمثا إلى غير إيجابي في كل من الربة والغوير. أخيرا، اظهر المزارعون تفضيلهم للأصناف ثنائية الصفوف على الأصناف السداسية وكذلك الأصناف ذات اللون الأبيض للبذور على الأصناف ذات اللون الأسود.

لم تكن هناك معنوية بالنسبة لمعامل الارتباط بين انتخاب المربين لصفة انتاج الحب والانتاج البيولوجي، وكان هذا المعامل أقل من معامل الارتباط بالنسبة لانتخاب المزارعين. كان وزن الحبة أكثر أهمية كصفة انتخاب بالنسبة للمزارعين مقارنة مع المربين، وكان كذلك أكثر أهمية من طول السنبلة وهذا يرتبط بشكل قوي مع انتخاب المزارعين في موقعي محي والرمثا.

أخيرا، كان معامل الارتباط لانتخاب المزارعين والمربين يتراوح من ايجابي ومعنوي في المواقع التالية: الخناصري، الرمثا، ومحي الى غير معنوي كما في موقعي الغوير والربة.

أظهر المزارعون في الدورة الاولى للانتخاب تفضيلاً جزئياً للاصناف ثنائية الصف، التي زادت من تكرارها من 70.7% في العشائر الاصلية الى 74 % في السلالات المنتخبة، هذا بالاضافة الى تفضيل قوي للانواع ذات البذور البيضاء حيث كانت زيادة التكرار من 66% الى 83 % في حين انخفضت مثيلتها في الانوع ذات البذور السوداء الى النصف.

الكلمات الدالة: الشعير؛ مشاركة المزارعين؛ تربية النبات بالمشاركة مع المزارعين؛ الظروف البيئية المجهدة.

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