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ICARDA and EIAR Success of Joint Barley-Breeding Program in Developing Food Barley Varieties for the Ethiopian Low-Moisture Areas

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Abstract: Collaborative work of international research institutes, like ICARDA and national agricultural research centers in any developing country, such as Ethiopia, is important and has significant impact on improving the livelihood of millions of farmers in such countries. Based on this initiative, the National Barley Breeding Program of Ethiopia viz., Ethiopian Institute of Agricultural Research (EIAR) introduces, every year, a number of genotypes developed by ICARDA for low-moisture areas for evaluation Ethiopian environmental condition. In 1998/99 and 2001/02 the Barley Breeding Program of EIAR introduced 600 genotypes from ICARDA, which are developed specifically for low-moisture areas. After evaluating these materials in different stage of breeding 9 genotypes from 1998/99 and 14 genotypes from 2001/02 introduction were selected for the national variety trial and tested at three different locations i.e., Asasa, Dhera and Arsi Negele in 2002/03-03/04 and 2007/08-08/09, respectively in comparison of the local check. The combined analysis over location and year showed significant differences among genotypes, location and year. Significant interaction effect was also observed on the effect of Location x Year. The significant interaction effect over year showed due to the erratic nature of rainfall in the low-moisture areas of the country. The mean separation test showed that the genotypes developed by ICARDA gave significant yield advantage over the local check that can reach 30% in 1998/99 introduction; besides these varieties showed plump kernel seed. From 1998/99 introduction, two varieties, namely EMBSN 5th 2/95-3-3-3 and EMBSN 5th 46/95-9-9-5, were released for production in 2006 by the National Variety Release Committee and named as Desta and Bentu. Similarly, 14 genotypes (selected from 2001/02 introduction) tested over year and locations. Significant difference among genotypes was observed over year and location. The ICARDA materials showed a great yield advantage over the local check, it reached as high as 20% and plumb grain. The farmers preferred these varieties due to high productivity and good grain character mostly not obtained by the landraces in low moisture areas of the country. In this group, the variety 7th EMBSN 19/98 released in 2008 by the National Variety Release Committee for production with the name Deribe. This variety got a large acceptance by the framers in the low moisture areas and in the belg season growing regions of Ethiopia. Therefore, this research shows the importance of collaborative work among the international research institute and the national research centers as having successful technology generation, especially for the low-moisture areas of the country.

Key words: Low moisture stress • Food barley • *Hordeum vulgare* L. • Genotype x Environment interaction

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the major cereal crops produced in Ethiopia. It is used for preparation of different foodstuffs, local drinks and beer. In Ethiopia, barley cultivated from the lowland (1650 m.a.sl) in the rift valley to high land about 3000 m.a.sl. According to the Ethiopian Statistical Authority in 2010 cropping season 1.2 million hectare of land was covered by barley, from which more than 1.0 million tons of grain were collected [1].

Drought is the principal constraint that reduced production of barley in the low-rainfall areas [2]. Even in these areas barley is one of the cereal crop performed well

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than other crops. The principal feature of barley adaptation for the drought prone area is early maturing [2]. Barley is the predominant and best alternative crop in the high and low land areas of Ethiopia receiving low rainfall, since it provide reasonable amount of grain for local consumption and marketing. The major yield limiting factors in these areas is the erratic rainfall pattern in the growing season year after year. Due to this, developing cultivars of barley with stable yield potential and well adapted to this situation is the objective of the breeding programs work in this type of environment.

The strategy employed for the selecting genotypes is evaluating the performance of the genotypes in the target environment due to the high genotype x environment interaction if selection is done for wide adaptation. This hypothesis is recommended by different researchers. Selecting genotypes under stress condition is recommended if the objective is to achieve significant yield gain in the target environment [3]. To get a progress in yield in stress environment selection should performed in those environment [4].

Until the recent time there is no any single variety released for the low moisture areas of the country by the breeding programs. To solve this problem the National Barley breeding program designed a joint project with the ICARDA barley breeding groups to develop food barley varieties suitable for the low moisture areas of the country. The objective of this program is to develop barley varieties that are high yielding and well adapted to the drought prone area of the country.

In this program the ICARDA barley improvement group developed crosses targeted to drought stress environment and provide seeds to the barley breeding program in Ethiopia. The Ethiopian barley breeding program evaluate them and select accessions with high yield, good grain character (TKW and HLW) and resistant to diseases and pests under the target environment. From this type of research activities 2 varieties from the 1999 introduction and 1 variety from 2003 introduction released by the national barley breeding program for the low moisture/ early production system of the country [5, 6].

Therefore, the objective of this study is to present the successful achievement obtained from the collaborative work among ICARDA and the Ethiopian national barley-breeding program to develop food barley cultivars for the low moisture areas of the country by selecting them in the target environment.

MATERIALS AND METHODS

Genotypes: Two sets of barley accessions (*Hordeum vulgare* L) introduced from ICARDA barley breeding program in 1998/99 and 2003 cropping season were used in this experiment. In 1999 (300) and 2003 (300) accessions were introduced. All the accession introduced from ICARDA first evaluated for new diseases and pests in the quarantine site of the Ethiopian Agricultural Research Institute at Holeta Research Center according to the guidelines developed by the Ministry of Agriculture. Those accessions passed the quarantine test were tested in yield trial program at Asasa, Dhera and Arsi Negele. The number of accessions introduced from ICARDA and selected at different stage of yield trials presented in Table 1.

Experimental Design and Description of the Test Location: Accessions evaluated in single plot for quarantine test and preliminary observation nurseries. The preliminary yield trial was laid using simple lattice design with two replications. The national variety trial and pre national variety trial were laid using RCBD design with 3 replications. The PON and PVT were planted at Dhera and Asasa experimental station which are located in Arsi Zone. The PNVT and NVT trials executed at Dhera, Asasa and Arsi Negle. Dhera is drought prone areas. Asasa and Arsi Negele represent those barley growing regions with terminal moisture stress. The selected genotypes introduced in 1999 (Set I) and 2003 (Set II) tested in locations described below. The plot size of 1.2 x 2.5 m was used for PVT, PNVT and NVT. For PON plot size of 0.8 x 1.5m was used. The description of the testing locations used for yield trials presented as follow. Arsi Negele lies on 7°20' N latitude and 38°09' E longitude at 1960 m.a.sl. Dhera located in the rift valley region of Ethiopia frequently suffer from moisture shortage due to erratic rainfall pattern. Asasa located in the Arsi zone of Oromia Regional State, which suffer usually due to terminal moisture stress.

Data Observation and Statistical Analyses: The days to heading, days to maturity, plant height, stand %, lodging %, disease data (Scald, Net blotch), 1000-kernel weight, hectoliter weight and grain yield per plot (kg) were recorded from each plot. The grain yield, days to heading, days to maturity, stand %, lodging % and diseases data (Scald, Net blotch and rust), TKW and

Table 1: The barley accessions introduced from ICARDA in 1998/99 and 2003/04 cropping season and the genotypes selected in each stage of breeding.

	Accessions introduced in 1998 (Set I)					
No accessions	(Quarantine) 1998/99	(PON) 1999/2000	PVT (2000/01)	PNVT (2001/02)	NVT (2002/03-03/04)	VVT (2004/05)
Tested	300	200	40	30	9	3
Selected	200	40	30	9	2	2
Discarded	100	160	10	21	7	1
	Accessions introduced in 2003 (Set II)					
	Quarantine (2003)	PON (2004)	PVT (2005)	PNVT (2006)	NVT (2007/08-08/09))	VVT (2010)
Tested	300	140	60	19	14	3
Selected	140	60	19	14	3	1
Discarded	160	80	41	5	11	2

Note: quarantine = test of accessions at quarantine site, PON = Preliminary observation nursery, PVT= preliminary variety trial, PNVT= pre national variety trial, NVT = National variety trial and VVT= variety verification trial

In each stage of breeding program the candidate varieties evaluated with the local check and compared for the measured agronomic traits and yield

HLW was measured in plot base. The plant height measured as average of 5 plants from each plot. The measured traits were subjected for statistical analysis. The ANOVA and mean separation test was done using GENES statistical analysis software [7]. The mean separation test trait among genotypes performed using Scott-Knott mean comparison test.

RESULTS

To make easy the interpretation of the data and discussion the result was presented in two set and only presented the result from the national variety trial. The first group (Set I) include the 1998/99 introduction and Set II (2003 introduction). In addition the result presented here is only the National variety trial of each set.

The ANOVA of Set I showed highly significant difference among genotypes for days to heading, days to maturity, plant height, 1000 kernel weight and grain yield (Table 2). All the characters showed significant difference among locations and year (Table 2). Significant interaction effect was not observed for Genotype x Location x Year (Table 2).

Accession EMBSN 5th 46/95-9-9-5 and EMBSN 5th 36/95-8-8-4 showed highly significant difference over the local check in 2003 cropping (Table 3). EMBSN 5th 36/95-8-8-4 gave the highest grain yield (4258.5 kg/ha) followed by EMBSN 5th 46/95-9-9-5 (4019.4 kg ha^{-1}) and these two genotypes gave significant yield advantage over the local check at P<5% over locations (Table 3). The candidate varieties EMBSN 5th 2/95-3-3-3, EMBSN 5th 46/95-9-9-5 and EMBSN 5th 36/95-8-8-4 gave 23.07, 23.77 and 31.07 % yield advantage over the local check (Table 3). The best three varieties showed resistance to scald and net blotch in the tested location in 2003 and 2004 cropping season. The accessions also showed acceptable hectoliter weight and 1000 kernel weight at both location and year (Table 3 and 4).

Set II, which include selection from 2003 introduction was tested as multi-location yield trial from 2004-2006. The ANOVA of the measured traits showed highly significant difference for genotypes, location, year and their interaction (Table 5). Days to heading, days to maturity, 1000-kernel weight and grain yield showed significant difference among genotypes and locations (Table 5). The grain yield comparison Table among the tested genotypes in relation to the local check showed significant yield advantage of the candidate varieties ranging from 6 to 57% (Table 6 and 7). The candidate variety 7th EMBSN 19/98 performed well across the location and year. It gave yield advantage of 42.2% over the local check. Besides the variety has a good seed quality trait such as hectoliter weight and 1000 kernel weight (Table 6 and 7). Days to heading, days to maturity and plant height of the candidate varieties and the local check was presented in Table 7. In relation to the disease reactions, all the candidate varieties showed tolerance to scald and net blotch (Table 6 and 7).

DISCUSSION

The candidate varieties introduced from ICARDA during 1999 and 2003 showed the green light in the development of food barley cultivars for the low moisture areas of Ethiopia. All candidate varieties selected and evaluated in yield trials showed good performance in relation to the local check. In Ethiopia, barley is grown from the low land areas with high moisture stress to the high land areas with high frost condition. In addition

Table 2: The combined analysis of variance table for days to maturity, days to heading, plant height, 1000 kernel weight and grain yield evaluated at Asasa, Dhera, Melkasa and Arsi Negele in 2003 and 2004 cropping season

	Mean squares					
Source of variation	Degree of freedom	Days to heading	Days to maturity	Plant height	1000 kernel weight	Grain yield
Year	1	112.067**	728.017**	1306.667**	1661.108**	25490418.87**
Location	3	3890.367**	13038.494**	20043.656**	117.20**	182047980.25**
Year x location	3	620.1**	659.828**	3671.278**	275.96**	20352552.30**
Replication(LY)	16	12.096**	21.75**	80.092**	9.09**	529668.40**
Variety	9	97.248**	106.35**	1105.813**	276.77**	1855777.38**
Year x variety	9	12.678**	7.48ns	50.583ns	7.65**	322887.81ns
Location x variety	27	8.237**	16.248**	43.288ns	24.55**	509553.74ns
Year x location x variety	27	9.97**	13.575**	25.91ns	6.65**	351842.30ns
Error	144	3.52	6.579	29.263	3.205	214979.93
Total	239	15824.40	44947.98	90222.73	6850.40	714989500.95

Table 3: The mean agronomic, disease and yield data of the tested genotypes at Asasa, Dhera, Melkasa and Arsi Negele in 2003 cropping season

No.	Variety name	DH	DM	Stand	Lodg%	PLH	Scald	Nb	HLw	TKW	G.yield (kg/ha)
1	EMBSN 37/96-1-1-1	52.1	81.6	87.3	0.8	71.8	0	1.8	63.3	36.6	3721.5
2	EMBSN 5th 2/95-3-3-3	51.2	79.8	92.6	3.8	74.5	0	1	66.3	35.2	3998.8
3	EMBSN 5th 36/95-8-8-4	52.7	84.4	91.3	15	64.2	0	1.2	62.4	38.2	4258.5
4	EMBSN 5th 46/95-9-9-5	53	85.6	90.1	8.8	66.8	0	0.8	64.4	40.4	4019.4
5	EMBSN 28/96-17-17-7	52.1	82.5	87.9	7.5	75.4	0	1.3	63	38.3	3864.6
6	EMBSN 22/96-24-24-9	50.7	81.3	88.2	7.9	71.8	0	1.6	63.1	36.4	3715.6
7	EMBSN 1/96-41-41-13	53.2	83.9	86.5	2.1	72.7	0	1.3	64	38.1	3480.9
8	EMBSN 43/96-42-42-14	50.8	81.8	88.8	0.8	73.7	0	1.3	62.8	39.4	3904.6
9	EMBSN 9/96-43-43-15	52.8	83.6	85.7	5.4	72.5	0	1.3	64.2	36.7	3493.9
10	Local check	56.7	85.8	93	36.3	93.8	0	1.3	64.9	46.1	3249
	LSD 5%										387.3

Note: DH= days to heading, DM= days to maturity, PLH= plant height (cm), NB= net blotch, HLW= hectoliter weight, TKW= 1000 kernel weight and G. yield= grain yield

Table 4: The mean agronomic, disease and yield data of the tested genotypes at Asasa, Dhera, Melkasa and Arsi Negele in 2004 cropping season

No.	Variety name	DH	DM	Stand	Lod%	PLH	Scald	NB	TKW	G.yield (kg/ha)
1	EMBSN 37/96-1-1-1	54.9	84.8	85.3	2.5	68.6	0.3	2.7	32	3094.2
2	EMBSN 5th 2/95-3-3-3	49.3	82.7	84.3	11.7	71	0	1.8	29	3374.8
3	EMBSN 5th 36/95-8-8-4	55.6	89.4	81.5	12.1	62.1	0.2	2.3	32.2	3472.5
4	EMBSN 5th 46/95-9-9-5	55.9	88.3	86.8	15.8	61.3	0.2	2.2	33.4	3173.8
5	EMBSN 28/96-17-17-7	53.8	87.4	84.8	9.6	72.8	0.3	2.8	32.4	3119
6	EMBSN 22/96-24-24-9	51.5	85.1	83.3	6.7	70.3	0.3	2.7	30.5	3420.4
7	EMBSN 1/96-41-41-13	54.8	87.3	89	3.3	67	0.3	2.6	32.9	3260.5
8	EMBSN 43/96-42-42-14	51.2	84.9	82.9	1.7	68.5	0.2	2.4	35.5	3041.1
9	EMBSN 9/96-43-43-15	54.4	84.9	77.9	2.5	66.8	0.3	2.5	32	2599
10	Local check	57.5	90.2	91.3	18.8	82.2	0.5	2.3	42.8	2633.5
	LSD 5%									367.1

Note: DH= days to heading, DM= days to maturity, PLH= plant height (cm), NB= net blotch, TKW= 1000 kernel weight and G. yield= grain yield, Lod%= Lodging percent

Table 5: The analysis of ANOVA table for days to heading (DH), days to maturity (DM), Plant height (PLH), TKW (1000 kernel weight) and Grain yield (GY) in 2004-2006 cropping season

		Agronomic traits				
Source of Variation	DF	DH	DM	PLH	TKW	Grain yield
Genotype (G)	15	567.29**	541.32**	2025.92**	972.74**	5.46**
Location (L)	2	13403.63**	40179.09**	66970.36**	2011.26**	401.49**
Year (Y)	2	2883.29**	1665.39**	11613.21	1252.37	15.89**
GxL	30	49.61**	40.82**	189.94**	29.07**	1.20**
GxY	30	43.26**	36.09**	129.00**	16.69**	1.66**
L*Y	4	403.64**	792.06**	12406.54**	240.84**	45.03**
GxLxY	60	31.40**	30.80*	128.40**	15.47**	1.83**
Error	423	12.06	20.32	58.48	5.19	0.56
CV (%)	(%)	5.96	4.7	10.27	5.69	20.04
R-sq		0.90	0.92	0.91	0.92	0.84

Note: DH= days to heading, DM= days to maturity, PLH= plant height (cm), TKW= 1000 kernel weight

Table 6: The mean agronomic and disease data of the tested genotypes over three locations in 2004/5 cropping season evaluated at Asasa, Dhera and Arsi Negele

No	Variety name	DH	DM	St%	Lod %	SC	NB	TKW	Grain Yield (kg/ha)	% yield advantage over check
1	EMBSN 36/94	59.3	97	86.1	10	0.3	2.8	34.6	3755.1	25.59
2	EMBSN 7/96	58.8	97.6	93.1	30	0.2	2.7	32.1	3628.6	21.36
3	7th EMBSN 28/98	71.1	108.6	89.5	38.8	1.3	2.5	27.3	2956.4	-1.12
4	EMBSN 37/96	53.5	91.2	88.6	5	0.2	1.7	32.7	4695.7	57.05
5	7th EMBSN 14/98	64.8	103.2	92	21.3	0.3	2.3	39.8	2959.5	-1.02
6	7th EMBSN 18/98	61.5	101.2	93.3	25.8	0.3	2.2	34	3818.5	27.71
7	7th EMBSN 19/98	58.8	96.7	91.3	29.2	0.2	2.4	34.2	3975	32.95
8	7th EMBSN 20/98	63.7	98	92	7.5	0	1.7	42.3	3207.5	7.28
9	26th IBON 83/98	61.9	99.4	93.1	17.1	0.1	1.8	36.3	3790.7	26.78
10	7th EMBSN 31/98	61.8	98.4	92.7	20.8	0.1	1.8	39.8	4078.7	36.42
11	7th EMBSN 44/98	65.5	100.9	89.9	22.5	0.3	2.3	37.6	3311.4	10.75
12	7th EMBSN 45/98	65.2	101	88.6	9.2	0.1	2.3	35.3	3208.2	7.30
13	7th EMBSN 48/98	57.1	95.7	92.4	5.8	0.2	2.5	36.6	4929	64.86
14	7th EMBSN 8/98	65.6	103.7	92.7	1.3	0.2	2	46.6	2949.6	-1.35
15	7th EMBSN 41/98	63.6	98	91	1.3	0.2	2.1	45.6	3333.7	11.50
16	local check	62	97.8	91.8	47.9	0.6	2.6	39.8	2989.9	0.00
	Mean	62.14	99.28	91.1	18.34	0.28	2.23	37.16	3599.219	
	CV %				76.49	136.52	37.46	6.24	19.88	
	LSD 0.05							4.034	1245	

Note: DH= days to heading, DM= days to maturity, Std= Stand %, Lod%= lodging %, PLH= plant height (cm), SC= Scald, NB= net blotch, TKW= 1000 kernel weight

barley is more suitable for the low moisture areas [8] since it has adapted well to the moisture stress condition of the dry land areas. Until now, the national barley breeding program not released a variety for this areas due to this the farmers produced their local landrace which is low yielding but give some harvest during the rain shortage [8].

The present result showed shat the possibility of developing high yielding cultivars with good grain character for the low moisture and early set growing regions of the country. From the 1999 introduction (Set I) the candidate genotypes performed well over the local check in grain yield. This is due to the fact that the candidate varieties are 6-rowed and the local check 2-rowed which gave more number of seed per head in case of 6 rowed ones. The significant effect Year x Location interaction showed that the existence of yearly rainfall variability in these areas (Table 2). The candidate varieties EMBSN 5th 2/95-3-3-3 and EMBSN 5th 46/95-9-9-5 from the Set I gave significant yield advantage over the local check

Table 7: Mean for some agronomic characters in FB/RVT-II for low moisture areas (2004-2006) evaluated at Asasa, Dhera and Arsi Negele

No	Variety name	DH	DM	PLH	Lod%	NB	Sc	TKW	GYLD (tons/ha)	% yield advantage over check
1	EMBSN 36/94	55	94	74	5	3	0	36.2	3.6	19.0
2	EMBSN 7/96	55	95	67	11	2	0	37.8	4.1	36.1
3	7th EMBSN 28/98	66	104	86	14	2	2	30.0	3.6	18.0
4	EMBSN 37/96	51	89	60	3	2	0	34.7	4.1	35.7
5	7th EMBSN 14/98	61	100	81	7	2	0	43.7	3.6	20.5
6	7th EMBSN 18/98	58	98	74	9	2	0	37.1	4.1	35.6
7	7th EMBSN 19/98	54	93	74	19	3	0	37.5	4.3	42.2
8	7th EMBSN 20/98	60	96	71	3	2	0	44.6	3.2	6.2
9	26th IBON 83/98	58	97	71	6	2	0	37.9	4.2	39.1
10	7th EMBSN 31/98	57	93	70	7	2	0	42.4	3.9	28.7
11	7th EMBSN 44/98	62	98	77	9	2	0	39.7	4.0	31.4
12	7th EMBSN 45/98	63	98	73	4	2	0	37.8	3.7	22.7
13	7th EMBSN 48/98	53	92	65	2	2	0	39.4	4.8	57.1
14	7th EMBSN 8/98	62	100	80	0	2	0	51.0	3.5	14.6
15	7th EMBSN 41/98	60	96	85	1	2	0	48.1	3.5	15.5
16	local check	57	92	85	54	3	1	42.5	3.0	0.0
	Mean	58	96	74	10	2	0	40.0	3.8	
	LSD (5%)	2.8	3.7	6.2				2.2		

Note: DH= days to heading, DM= days to maturity, Std= Stand %, Lod%= lodging %, PLH= plant height (cm), Sc= Scald, NB= net blotch, TKW= 1000 kernel weight, GYLD= Grain yield

(Table 3 and 4). These varieties also gave comparable 1000-kernel weight to the local check. In contrast the candidate barley varieties gave high yield with acceptable 1000 kernel weight. From the Set I, two candidate varieties EMBSN 5th 2/95-3-3-3 and EMBSN 5th 46/95-9-9-5 released for production by the variety released committee in 2006 and named Bentu and Desta [5]. These varieties also got wide acceptance by the farmers in the region due to its productivity.

In the second set (Set II) significance difference is observed among genotypes. The performance of the genotypes over location and year also vary (Table 5). This reflected the exact nature of the low moisture areas of the country. In this set of the experiment in contrast to the first set all the interaction effects showed significant difference. The candidate variety 7th EMBSN 19/98 which is released as Deribe in 2010 [6] gave more than 40% yield advantage over the local check which is significant and very promising. Since improving the productivity of barley in these areas can ensure food self-sufficiency for the small scale farmers frequently affected by drought.

In addition the comparison of important grain characters such as 1000 seed weight showed that the local check (landrace) gave better seed size than the candidate varieties this is resulted from the two rowed nature of the local check in contrast all the candidate varieties are six rowed relatively produce lower seed weight. The candidate variety 7th EMBSN 19/98 which released in 2009 for production gave 37 gm (TKW) where the landrace gave 41 gm (Table 6 and 7). The candidate variety 7th EMBSN 19/98 released as Deribe also got good acceptance by the farmers due to its productivity and grain plumpness that mostly preferred by them due to its market value. The other extra advantage of this variety is, the variety also performed well in the belg season growing regions of the country. In Ethiopia some regions have two growing seasons the long and short season, the short season called belg and this variety got wide acceptance and adaptability in these regions of the country. This research showed that it is possible to develop varieties for the two production system that is the low moisture (mostly early set) and the belg season at the same time.

The achievement presented in this paper showed the importance of the collaborative work between ICARDA and the National barley research program of Ethiopia in developing varieties suitable for the low moisture areas of the country. In addition it is important to develop the skill of the researcher and the technician about the techniques of evaluating drought tolerance traits besides conventional method such as evaluating for yield. This may help identify some genotype with the drought tolerant trait and incorporate it in the future breeding program of barley in the country.

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