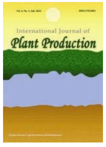

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Wheat and barley seed system in Syria: How diverse are wheat and barley varieties and landraces from farmer's fields?

Z. Bishaw[a,*], P.C. Struik[b], A.J. G van Gastel[c]

[a] *Seed Section, ICARDA, P.O. Box 5466, Aleppo, Syria.*
[b] *Center for Crop Systems Analysis, Wageningen University, Wageningen, The Netherlands.*
[c] *Harspit 10, 8493KB, Terherne, the Netherlands.*
*Corresponding author. E-mail: z.bishaw@cgiar.org

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Abstract

The present study described the diversity of wheat and barley varieties and landraces available in farmer's fields in Syria using different indicators. Analysis of spatial and temporal diversity and coefficient of parentage along with measurements of agronomic and morphological traits were employed to explain the diversity of wheat and barley varieties or landraces grown by farmers in Syria. Farm level surveys showed low spatial diversity of wheat and barley where only a few dominant varieties occupied a large proportion of wheat and barley areas. The five top wheat varieties (ACSAD 65, Cham 1, Cham3, Lahan and Cham 6) occupied 81% of the wheat area and were grown by 78% of the sample farmers. In case of barley one single landrace was grown in almost the entire survey area in north eastern Syria. The weighted average age of wheat varieties was highest with an average of 10.8 years showing low temporal diversity by farmers. In Syria bread wheat showed lower average diversity and weighted diversity than durum wheat. Variance component analysis showed significant variations for desirable agronomic characters such as plant height, grain yield and yield components (kernels per spike^{-1}, seed weight) among wheat and barley varieties and landraces. The principal component analysis explained the variations that existed among modern varieties and landraces. Cluster analysis based on agronomic and morphological traits grouped the modern varieties and landraces into separate clusters. The variation that existed among the landraces showed broad opportunities for using in plant breeding programs to develop varieties suitable for different agro-ecological zones. To date large areas previously grown to traditional varieties and landraces are now increasingly replaced by contiguous expanse of land planted to uniform modern bread and durum wheat varieties and are grown by large number of farmers. Apart from the landraces, the wild relatives and progenitors of both wheat and barley are being threatened by extinction in the center of origin.

Keywords: Syria; Barley; Wheat; Genetic diversity; Spatial diversity; Temporal diversity; Coefficient of parentage.

Introduction

Crop genetic resources, a combination of weedy species, wild relatives and domesticated crops (including landraces and modern varieties) form the pool of genetic diversity available in a given agro-ecosystem shaped through centuries of natural and/or human selection. Such crop genetic diversity is very important from agro-ecological, agronomic, economic and socio-cultural perspectives because it offers variation for selection in crop improvement by modern plant breeders and provides farmers with a wide range of choices to select varieties adapted to their specific niche environments.

The Fertile Crescent is believed to be the center of crop domestication and agricultural innovation where farming started as early as 10,000 years ago. The domestication of barley was followed by that of wheat from their wild relatives to cultivated crops. Primitive forms and wild relatives of wheat and barley still exist in the wild throughout the Middle East and the Mediterranean region. Syria is located in the 'center of origin' of wheat and barley (Damania et al., 1998). Such valuable genetic diversity of plant resources is rapidly declining due to natural and human activity. Since mid-1960s several modern wheat and barley varieties were released for commercial production in Syria (Mazid et al., 1998). The extent of adoption and diffusion of modern varieties of wheat and barley has been described in Syria (Bishaw, 2004; Bishaw et al., 2011). Today, there is great concern over the loss of genetic diversity, particularly with the substitution of a diverse set of genetically variable crop landraces with few genetically uniform modern varieties particularly in areas of crop domestication such as Syria. Although the loss of biodiversity is largely due to replacement of 'local' landraces' by 'improved' varieties, population pressure, urbanization and environmental degradation such as recurrent droughts, overgrazing and desertification are also contributing to the decrease in natural genetic variability.

However, information on the status of genetic diversity at the farm level is rather limited (Souza et al., 1994; Witcombe et al., 2001). Earlier studies, for example, have described the diversity of barley landraces from Syria in terms of agronomic performance and disease resistance (Ceccarelli et al., 1987; van Leur et al., 1989). However, information on on-farm genetic diversity is rather limited in both crops.

The present study was aimed at assessing the on-farm wheat and barley diversity using different approaches and tools. Therefore, the main objectives of this study were to (i) measure the spatial and temporal diversity of wheat and barley varieties planted by the farmers and (ii) investigate the agronomic and phenotypic traits diversity of wheat and barley varieties used by farmers.

Materials and Methods

Field Surveys

A total of 206 wheat and 200 barley farmers were interviewed in major wheat and barley growing regions as part of seed system study (Figure 1). A stratified sampling procedure based on the proportion of wheat or barley area in each region, followed by random sampling of farmers was employed (Bishaw et al., 2011). Three provinces were included, covering 6 districts and 59 villages. Farmers were asked about wheat and barley varieties and landraces they grew and their perceptions and seed sources and seed management practices. After the interview, a seed sample of about 1 kg was collected from each farmer from the seed lot planted or intended for planting for field experiments.

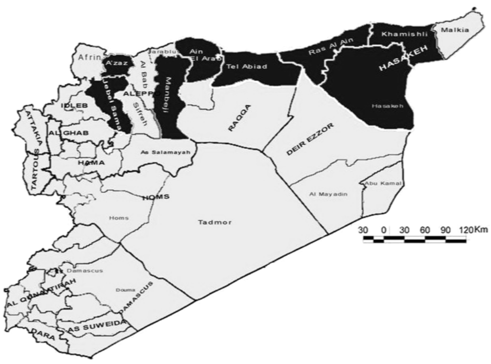

Figure 1. Wheat and barley seed system study areas (shaded) in Syria.

Field Experiments

The experiment was planted at Tel Hadya (latitude 36° 01′ N, longitude 36° 56′ E) ICARDA Research station on soil with fine clay (montmorillonitic) of pH ranging from 7.9 to 8.2. From 204 wheat seed samples collected from different parts of Syria, 60 samples representing 6 bread wheat (5 modern, 1 obsolete) and 7 modern and 5 landraces (represented by 1, 4, 4, 5 and 7 populations) of durum wheat were selected and planted for two cropping seasons (1998/99 and 1999/00) to assess the genetic diversity of wheat and barley. The modern bread wheat varieties included were Cham 2, Cham 4, Cham 6, Bohouth 4 and Bohouth 6 and an obsolete variety (Mexipak). The durum wheat cultivars included modern varieties (ACSAD 65, Bohouth 5, Gezira 17, Cham 1, Cham 3, Cham 5 and Lahan) and landraces collected from isolated areas (Bayadi, Hamari, Hourani and Swadi). Since all barley seed samples collected from farmers were identified as single landrace, Arabi Aswad, two seed samples from each village were selected where 50 samples were planted at two contrasting environments at Tel Hadya and Breda representing two contrasting agroclimatic zones where barley is one of the major crops.

Modern varieties and landraces were grouped into bread and durum wheat and planted separately to study the diversity among them using agronomic and morphological (phenotypic) characteristics. Wheat samples were planted in a RCBD design with three replications for two consecutive years (2 replications for barley). Bread wheat was planted at the rate of 60 g and durum wheat at 70 g per plot in 8 rows of 2.5 m length with a spacing of 0.25 m between. Barley was planted at the rate of 50 g per plot of 8 rows of 2.5 m length with a spacing of 0.25 m at Tel Hadya and Breda experimental farms. Fertilizer was applied at the rate of 180 and 150 kg ha^{-1} of ammonium nitrate and triple superphosphate at Tel Hadya both for wheat and barley. In addition, N was applied as top dressing at the rate of 120 kg ha^{-1} for wheat at Tel Hadya. In Breda 90 kg ha^{-1} of ammonium nitrate and 60 kg ha^{-1} triple superphosphate were applied for barley, all at planting time.

The agronomic and/or morphological characteristics were recorded on a plot basis in the field or after harvest. Agronomic characters measured included days to heading, days to flowering, days to maturity, grain yield, biomass yield, plant height, spike length, number of spikelets $spike^{-1}$, number of kernels $spike^{-1}$ and thousand seed weight. Morphological characters were measured visually on a plot basis or on a group of plants (UPOV 1981 and 1988).

The following agronomic and morphological characters were recorded during the field experiments:

(i) Agronomic characters (on a plot basis or on 10 randomly selected plants)

1. Days to heading (days): Number of days (counted from first effective date of rainfall to) when 75% of the plants were heading in the plot;
2. Days to flowering (days): Number of days (counted from first effective date of rainfall to) when up to 50% of the plants flowering in the plot;
3. Days to maturity (days): Number of days (counted from first effective date of rainfall to) when 90% of plants reaching physiological maturity in the plot;
4. Grain filling period (days): number of days to maturity minus number of days to heading;
5. Plant height (cm): Length of randomly selected plants measured from the ground (excluding the awns) at maturity;
6. Number of tillers plant^{-1}: number of tillers of randomly selected plants counted at maturity;
7. Grain yield (g): grain weight of four middle rows harvested at maturity and measured after threshing and cleaning;
8. Biomass yield (g): biomass (straw and grain) weight of 4 middle rows harvested and weighed at maturity;
9. Spike length (cm): Length measured from base of spike to top excluding the awns at maturity;
10. Number of spikelets spike^{-1}: Number of spikelets on randomly selected plants counted at maturity;
11. Number of kernels spike^{-1}: Number of kernels counted on randomly selected plants per spike at maturity;
12. Thousand seed weight (g): Weight of 1000 seeds calculated at 12% moisture content.

(ii) Morphological or phenotypic characters (observed on plot basis or 10 randomly selected plants)

13. Growth habit: scored as prostrate, semi-prostrate, intermediate, semi-erect, erect;
14. Plant characters: hairiness of uppermost node (HUN), glaucocity of ear neck (GN), zigzagness of neck (ZICN);
15. Leaf characters: auricle coloration, glaucocity of leaf sheath and lower leaf blade;
16. Glume characters: glume color (GC), beak length (BL), shoulder shape (SHSH), shoulder width (SHW);

17. Ear characteristics: ear shape (ES), ear color (EC), awn condition (presence or absence), awn color (AC);
18. Grain characters: grain color (GC), grain shape (GS), brush hair (BRH).

Some of the quantitative characters were measured on a scale of 1 to 9. For example for growth habit the score was erect (1), semi-erect (3), intermediate (5), semi-prostrate (7) and prostrate (9). The qualitative characters were measured on a discontinuous basis such as absent (1) or present (2). For example ear shape could be scored as tapering (1), parallel (2), semi-clavate (3), clavate (4) or fusiform (5).

In barley, however, only the number of days to flowering, tillers per plant, plant height, grain yield, spike length, number of kernels per spike and ear density (ratio of grains to spike length) were recorded.

Data Analyses

Field Surveys

The number of varieties grown by each farmer and the proportion of area under each variety was used to measure the spatial and temporal diversity on the farm. The weighted average age of varieties was used to estimate the temporal diversity of the varieties (Brennan and Byerlee, 1991) grown during the 1998/99 crop season in Syria. Moreover, measuring the varietal diversity also requires information on the genetic relatedness between varieties. The matrix of coefficients of parentage (COP) among the released wheat varieties was generated using the International Wheat Information System version 4 computer program (Payne et al., 2002). The COP measures the theoretical genetic relationship between two varieties based on the analysis of their pedigrees (St. Martin, 1982) where the COP of each unique wheat variety with itself is one; two varieties without common parentage is zero; each parent contributes equally to the progeny and any unrelated parents has a relationship of 0.5 with the progeny; and a variety without a known pedigree is unrelated (COP=0). The average diversity is the average value of the COP among all cultivars (including the COP of a cultivar with itself) grown within each year and region subtracted from 1 (Souza et al., 1994). The weighted diversity is determined from a matrix of the COPs where each cell in the matrix is weighted by the proportion of the area grown to each variety and the weighted mean COP is subtracted from 1 (Witcombe et al., 2001).

Field experiments

The data from the field experiments were analyzed using the residual maximum likelihood estimation (REML Genstat 6.1) to test the significance of variation among the genotypes and to estimate variance components. Moreover, the data was pre-standardized to overcome differences in measurements used for recording data before carrying out the multivariate analysis (principal component analysis and cluster analysis). Principal component analysis was performed using the correlation matrix to define the patterns of variation among the varieties or landraces or the collection sites based on the mean of agronomic and phenotypic traits measured during the study using the SPSS 11.1 statistical software and the graph plotted with NTSYS pc 2.1 software. Clustering was made using the hierarchical cluster analysis. Euclidean distance was used as cluster distance measure and the clustering method was unweighted pair group using arithmetic average (complete linkage used for barley) using NTSYSpc 2.1. The actual data matrix was compared with a calculated cophenetic value matrix to evaluate the degree of fitness between the two matrices (r) performing Mantel test (Mantel, 1967).

Results and Discussion

Spatial Diversity of Wheat Varieties

In 1998, from 206 wheat farmers sampled 51, 32 and 17% grew durum, bread or both wheat types, respectively. About 16 wheat varieties (eight each of durum and bread wheat) were found grown by farmers excluding the landraces. The number of wheat varieties grown per farm is given in Table 1. The diversity of wheat varieties on the farm was exceptionally low both for bread and durum where 96 and 84% of the farmers, respectively, planted only one variety. Few farmers (4% for bread wheat and 16.5% for durum) planted more than one wheat variety. Similarly, the result remained for both bread and durum wheat. Wheat farmers in Hasakeh and Raqqa provinces were more inclined to concentrate on a single variety of wheat than farmers in Aleppo probably because of relatively large areas for mechanization. The findings are similar to reports for durum wheat in Syria (Mazid et al., 1998). Despite diversity of landraces among communities, individual farmers continue to depend on single landraces and a few landraces continue to dominate the farming landscape. Louette et al. (1997) also reported that from 26 maize varieties grown by farmers four varieties were planted by the majority of farmers and almost occupied 80% of the maize area, showing low spatial diversity even in traditional farming systems. On the other hand reports from elsewhere showed more varietal diversity on the farm where 81% (n=75) and 60% (n=35) of farmers, respectively grew more than two varieties of sorghum and pearl millet, although the diversity of other (minor) crops was less (Mpande and Mushita, 1996).

Table 1. Number of bread and durum wheat varieties grown by farmers (n=241) in Syria.

Number of varieties	Aleppo		Raqqa		Hasakeh		Total	
	Farmers	%	Farmers	%	Farmers	%	Farmers	%
All wheats								
1	72	82	32	94	110	92	215	89
2	11	13	2	6	9	8	22	9
3	5	6	0	0	0	0	5	2
Total	88	101	34	100	119	100	241	100
Bread wheat								
1	30	94	20	95	47	98	97	96
2	2	6	1	5	1	2	4	4
3	-	-	-	-	-	-	-	-
Total	32	100	21	100	48	100	101	100
Durum wheat								
1	42	75	12	92	63	89	117	84
2	9	16	1	8	8	11	18	13
3	5	9	-	-	-	-	5	4
Total	56	100	13	100	71	100	140	101

Note: - = no farmers.

At the community level the number of varieties grown was fairly low. In the survey area 33 out of 61 villages grew a single bread or durum wheat variety. More farmers in Hasakeh tended to grow a single variety because this was associated with a government policy of ‘closed’ areas in producing some wheat varieties as part of export promotion to meet certain grain quality standards. The wisdom of such practice is not clear in case of breakdown of disease resistance. However, the rapid technological changes in agricultural production in general and cereal production in particular might contribute to monocropping and use of limited number of varieties at the farm level. The five possible points that may explain the phenomenon could be (a) a trend towards intensification of agriculture where productivity is a more important incentive for farmers than diversity of crops and products, (b) the ease of crop management where all field activities could be undertaken in a single operation for a specific crop variety rather than different varieties competing for labor and resources, (c) lack of differences among wheat varieties fitting specific niche environments, (d) the lack of difference in yield and agronomic management among existing wheat varieties and (e) ease of marketing wheat grain at a premium price to the government without any specific market quality requirements.

The proportion of farmers growing the top six varieties of wheat varieties over a four-year period from 1995/96 to 1998/99 cropping season is presented in Figure 2. The total number of wheat varieties grown remains the same, although few durum landraces such as Dahabi and Hamari were dropped as farmers are adopting new varieties. On the other hand, few bread varieties (Lagous and Memof) entered the production, before they were officially released. Memof was later released as Cham 8 in 2000. This demonstrates the spectacular leakage of some successful modern varieties from research stations without going through formal release and registration procedures (Cromwell, 1990), which can be exemplified by Lahan, a durum wheat variety, was not officially released by the national agricultural research system due to its late maturity (15 days late) and high water requirement in Syria.. However, the variety was very popular with farmers because of its high response to inputs and therefore spread through lateral farmer-to-farmer seed diffusion mechanisms. The variety is suitable for irrigated areas and gave a grain yield advantage of 16 and 4% over Gezira 17 and Cham 1 durum wheat varieties, respectively.

The top five wheat (bread and durum) varieties, on average, were planted by 77.7% of the farmers. ACSAD 65, Cham 1, Cham 3 and Lahan among durum wheat and Cham 6 among bread wheat varieties remained dominant. Cham 3 was a single most popular variety, although it was dropped significantly from around 40% in 1995 to 25% in 1999, if both wheat types were considered together. These percentages would be substantially higher if the two wheat species considered separately. The proportion of farmers growing early generation modern durum wheat varieties was declining (Figure 2). ACSAD 65 and Cham 1 were grown by less than 10% of the farmers. On the other hand the proportion of Bohouth 5, Cham 5 and Lahan was increasing as farmers were adopting new varieties released in the 1990s. In case of bread wheat Cham 4 and Cham 6 remained popular with the farmers and the proportion showed an upward trend (Figure 2). The number of farmers growing these two varieties doubled over a four-year period from

5 to 10% for Cham 4 and from 10 to 20% for Cham 6. The older bread wheat varieties and earlier releases such as Cham 2 and Mexipak were grown by less than 5% of the farmers surveyed. If one discounts few 'obsolete' varieties and landraces in isolated pockets, the entire population of wheat growers planted a handful of bread and durum wheat varieties. In early 1990s, Mazid et al. (2003) also found that Cham 1 and Cham 3 covered about 63% of the durum wheat area and was planted by 56% of the farmers showing high level of varietal concentration.

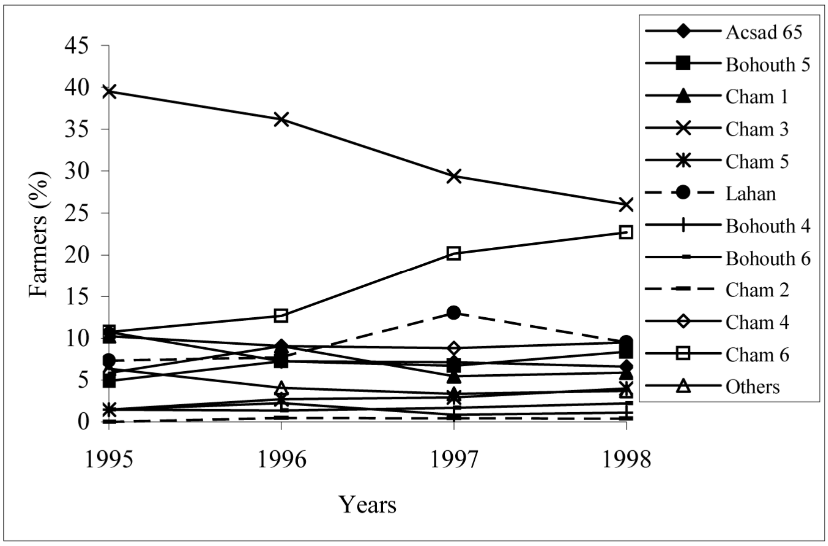

Figure 2. Temporal diversity of bread and durum wheat varieties grown by farmers in Syria.

Figure 3 presents the area allocated to top bread and durum wheat varieties grown over a four year period by sampled farmers. The proportion of area allocated appeared to be consistent with the national statistics, 71% for durum and 30% for bread wheat. However, the durum wheat area is trending downward whereas that of bread wheat is on the increase. The availability of irrigation facilities enabled farmers to grow bread wheat varieties outside their recommendation domains in less rainfall areas increasing the scope for on-farm crop diversification. However, on average the top five bread and durum varieties together occupied about 81% of the wheat area. Among durum wheat varieties, Cham 3 occupied the largest proportion of area although this trend is declining over the four year period from around 40% to nearly a quarter of the area in 1999. ACSAD 65 and Cham 1 were also in the declining trend whereas the newer varieties such as Bohouth 5 and Cham 5 were showing an upward trend as farmers seeking new varieties. Lahan, a non-recommended durum wheat variety still occupied about 10% of the wheat area, exhibiting the resilience of informal seed diffusion system. In case of bread wheat Cham 6 appeared to cover the highest proportion of the area followed by Cham 4.

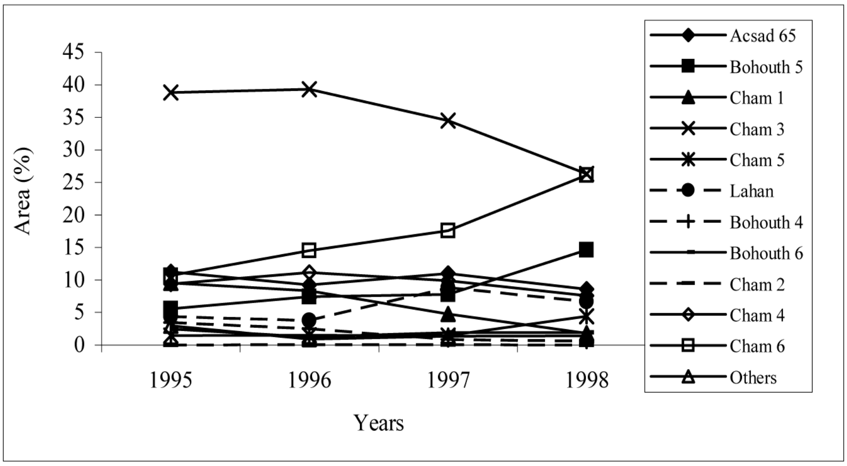

Figure 3. Spatial diversity of bread and durum wheat varieties grown by farmers in Syria.

The most interesting observation during the field survey was the situation of durum landraces. Most farmers acknowledged that in the past they were extensively growing landraces such as Bayadi, Dahabi, Hamari, Hourani, Swadi. At present these landraces were virtually replaced by modern varieties that are high yielding and responsive to improved management practices including use of fertilizers and irrigation water in all major wheat production areas of the country. All traditional landraces were tall and had a problem of lodging under high input conditions and therefore did not present economic benefits to those farmers investing in new technologies. In consequence, durum landraces were under cultivation in isolated pockets where some farmers still use traditional practices including organic fertilizers (manures) and no seed treatment. A comparison made between the landraces and modern varieties showed an interesting result. Farmers recognized that modern varieties give high yield and disease resistance but give low straw yield and quality (short plant height) and have high requirement for water and inputs. On the other hand, the landraces give low yield, but excellent grain quality, good tolerance to frost, heat and shattering and high straw yield and quality. Farmers claim the landraces have excellent quality in preparation of traditional foods i.e. soft grains, less time for cooking, less ingredients for food preparation and above all an excellent taste. Moreover, most of the landraces were mainly grown for home consumption where there are differences on the household use. Some landraces are preferred for *burghul* and *kibbe* than for *frekeh* which give farmers an incentive to grow them. The landraces also have a range of kernel color and size: white for Bayadi, red for Hamari and black/dark for Swadi. Apart from home consumption, farmers also sell the grain of landraces within the village or local traders who often pay premium prices compared to grain of modern varieties.

The important features observed are: (a) the dramatic decline in the proportion of area under durum landraces and their complete replacement with modern varieties; (b) decrease in the area of previously dominant durum wheat varieties such as Cham 1 and Cham 3 as more farmers adopting newer releases; (c) increase in the proportion of bread wheat varieties such as Cham 4 and Cham 6; and (d) the persistence of older varieties such as Mexipak and Cham 1 in the farming system. It can be observed that bread and durum wheat production is dependent on few selected modern varieties where traditional landraces were being completely replaced in major wheat growing regions. These results once again demonstrated a high degree of cultivar concentration where the vast majority of farmers grew few varieties covering a large expanse of land.

Temporal Diversity of Wheat Varieties

From 1970 to 1998, eight durum and six bread wheat varieties were released by the national agricultural research system in Syria with an average of 4.7 varieties per decade (data not shown). There was not much difference in the number of modern varieties released between the two wheat types. However, there was remarkable adoption and diffusion of theses limited number of bread and durum wheat varieties by the majority of farmers.

The weighted average age (WA) for bread and durum wheat varieties was close to 11 years (Table 2). The figure is higher than the previous reported WA of 6.8 years (Mazid et al., 1998). Moya and Piedad (1993) estimated a range of 6 to 8 years weighted average age for wheat varieties, although recent literature showed a much higher figure of 12.7 years (Smale et al., 1996). In the 1970s, the area planted to improved wheat was dominated by introductions from elsewhere (Bailey, 1982; Mazid et al., 1998; Mazid et al., 2003). However, at present the percentage of farmers growing modern varieties and area covered with new varieties released in the late 1980s and early 1990s is higher than for improved tall varieties introduced previously (Mazid et al., 2003). Farmers in Syria tend to replace modern wheat varieties in relatively shorter period of time and therefore obtain better benefit from newly released varieties compared to farmers in Ethiopia or elsewhere. At present, the high average age of varieties and predominance of few varieties indicate low on-farm varietal diversity. The WA may likely continue to increase unless new and well adapted and high-yielding varieties with better grain quality are released and adopted by farmers. For example, after the survey year the national agricultural research system released 2 bread and 3 durum wheat varieties for commercial crop production.

Table 2. Weighted average age of bread and durum wheat varieties in Syria.

Variety	Year of release	Years since release	Mean area in 1998 (ha)	WA
Acsad 65	1987	11	11.31	1.47
Bohouth 5	1987	11	15.03	1.96
Cham 1	1984	14	2.66	0.44
Cham 3	1987	11	8.74	1.14
Cham 5	1994	4	9.50	0.45
Gezira 17	1975	23	5.00	1.36
Bohouth 4	1987	11	4.67	0.61
Bohouth 6	1991	7	7.42	0.62
Cham 2	1984	14	0.50	0.08
Cham 4	1986	12	6.87	0.98
Cham 6	1991	7	9.92	0.82
Mexipak	1971	27	2.75	0.88
Total				10.82

WA= weighted average age.

Coefficient of Parentage of Wheat Varieties

ICARD wheat breeding program was successful in developing varieties that are adapted to stress environments and at the same time responsive to better management practices (Mazid et al., 2003). Almost all wheat farmers have adopted both modern bread and durum wheat varieties. The coefficient of parentage (COP) for bread wheat varieties is given in Table 3. Cham 2 has high COP values in decreasing order with Mexipak (0.420), Cham 4 (0.332) and Bohouth 6 (0.248). The bread wheat varieties have a mean COP of 0.27 (excluding Cham 2). Therefore, the average diversity calculated based on the mean COP was 0.73 showing values comparable to similar diversity studies of bread wheat varieties based on COP analysis (Souza et al., 1994). The persistence of old varieties may increase the average diversity but may reduce the temporal diversity of varieties. Much higher average diversity was reported for other crops elsewhere (Martin et al., 1991). The weighted diversity, however, was 0.42 showing a very low diversity of bread wheat varieties at the farm level. This is understood given the fact that Cham 6 was the dominant variety grown by almost 70% of bread wheat producers followed by Cham 4 (21%).

Table 3. Coefficient of parentage matrix for bread wheat varieties in Syria.

W^1	Cham 4	Cham 6	Bohouth 4	Bohouth 6	Mexipak
	0.207	0.711	0.016	0.052	0.014
Cham 4	1	0.070	0	0.169	0.290
Cham 6		1	0	0.068	0.077
Bohouth 4			1	0	0
Bohouth 6				1	0.239
Mexipak					1

Note: W^1= proportion of wheat area planted to each variety used for calculating the weighted diversity.

In durum wheat, however, the COP values are unknown except between ACSAD 65 and Cham 1 (0.188). Cham 5 (42%), Bohouth 5 (23%) and Lahan (11%), which occupied a large proportion of the durum wheat area, appeared to be unrelated to each other. The average diversity of 0.85 would be obtained if all durum varieties with over 0.1% wheat area would be considered and kept as unrelated for the COP analysis (data not shown). The average diversity is higher with unrelated varieties compared to when many related varieties are grown. However, excluding varieties that are not related from the analysis will increase the mean COP and will reduce the average diversity of durum wheat substantially. The weighted diversity for durum wheat calculated based on the proportion of area of wheat varieties grown was 0.73. The weighted diversity was higher in durum compared to that of bread because of the difference in the number of unrelated varieties grown by farmers.

The average and weighted diversity using the COP analysis indicated that durum wheat varieties were more diverse compared to those of bread wheat. The main factors contributing to these differences could be: (a) in durum wheat farmers plant more unrelated varieties compared to bread wheat which contributes to high average diversity; (b) the proportion of area planted by durum varieties is more than that of bread wheat contributing to higher weighted diversity; and (c) there are relatively more variety releases for durum wheat than for bread wheat.

Wheat Traits Diversity

Most of the agronomic traits measured showed variation within and among bread and durum wheat varieties (Table 4). The average number of days to heading was 109 (ranged from 103 to 121 days) for bread wheat whereas the number of days was relatively shorter for durum wheat varieties. Variation in days to heading and maturity will provide the scope for flexible date of planting under rainfed conditions where the onset of rain quite often is unpredictable in dry areas. Bread wheat varieties had shorter plant height (46 to 83 cm) with an average of 60 cm compared to durum wheat varieties with an average of 71 cm and a range of 43 to 117 cm. This difference could be attributed to the presence of durum landraces which were consistently taller than the modern durum varieties. There is a large variation in grain yield and biomass yield within the bread and durum wheat varieties. Modern durum wheat varieties consistently gave higher yield than landraces, although few local materials gave comparable grain yield. Cham 3 and Lahan (not released) gave the highest grain yield among modern durum varieties. On the other hand, the landraces exhibited the highest biomass yield. Mexipak, the oldest improved variety, gave lower grain and biomass yields than recently released bread wheat varieties.

The average spike length and number of spikelets spike^{-1} for bread wheat were 9.3 cm (with a range from 6.3 to 13.8 cm) and 19.5 (range from 16.0 to 26.4), respectively. In case of durum wheat the average spike length was 6.6 cm and the number of spikelets was 20.2. These results were in agreements with previous studies conducted in Syria. Kayyal et al. (1995) found significant differences for grain yield components and grain quality traits among released and promising bread and durum wheat varieties in Syria. Such genetic variations among bread and durum wheat varieties offer great opportunity for crop improvement and increasing the yield potential of wheat in dry areas.

Table 4. Mean, minimum, maximum, standard error of mean for agronomic traits of bread and durum wheat varieties/landraces in Syria.

Agronomic characteristics	Bread wheat			Durum wheat		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Number of tillers plant^{-1}	0.4	6.9	2.85± 0.1	1	5	2.18± 0.1
Days to heading (d)	103	121	110 ± 0.6	87	117	103 ± 0.5
Plant height (cm)	46	83	60.1 ± 0.9	43	117	71.3 ± 1.2
Grain yield (kg ha^{-1})	322	2310	1124 ± 40	518	2120	1271 ± 22
Biomass yield (kg ha^{-1})	858	9297	5847 ± 170	2845	9948	6498 ± 119
Spike length (cm)	6.3	13.8	9.26 ± 0.1	4.8	8.9	6.62 ± 0.1
Number of spikelets spike^{-1}	16	26.4	19.6 ± 0.2	14	30.9	20.2 ± 0.2
Number of kernels spike^{-1}	18.8	43.8	31.2 ± 0.7	15.3	39.0	25.6 ± 0.4
Ear density (ratio)	1.8	3.1	2.1 ± 0.02	1.9	4.2	3.1 ± 0.03

Correlation Coefficient Analysis

In bread wheat plant height had a positive and significant correlation ($P \leq 0.05$) with grain yield and biomass yield, but a highly significant negative correlation ($P \leq 0.01$) with days to heading. Days to heading were negatively correlated with biomass yield ($P \leq 0.05$) (Table 5). Grain yield had strong and positive correlation with biomass yield. In durum wheat more association was observed among agronomic traits compared to bread wheat. The number of tillers per plant had positive and strong significant correlation with grain yield ($P \leq 0.05$) and biomass yield ($P \leq 0.01$). In durum wheat the plant height had a negative, but significant correlation with grain yield and number of spikelets and kernels spike^{-1} ($P \leq 0.01$) and spike length ($P \leq 0.05$) and possibly because of the taller landraces with less yield and short spike length. Grain yield had a positive and significant correlation with number of spikelets per spike ($P \leq 0.01$). Similarly, the spike length had a positive and significant correlation with the number of spikelets. The presence of two types of genotypes within the experimental plots led to variation in morphological traits. In an earlier study, Kayyal et al. (1995) reported a negative non-significant correlation between yield and days to heading, days to maturity, plant height and spike length (except spikelets per spike) among recommended wheat varieties and promising lines in Syria. They also found positive correlation between spike length and number of spikelets; spike length and seed weight; and days to heading and maturity; and spike length and days to maturity. However, a negative association was reported for days to maturity with number of plants and spikelets m^{-2}. Such variation and association of agronomic traits with yield and yield components has far reaching implications for breeding bread and durum wheat varieties with desired varietal characteristics for farmers to adopt and use them.

Variance Component Analysis

The variance component analysis showed more variation among durum wheat varieties than among the bread wheat varieties for agronomic traits measured (data not shown). The greater variation among durum wheat observed was mainly due to inclusion of landraces collected from isolated sites. A significant difference ($P \leq 0.001$) was observed among bread wheat varieties in terms of tillers per plant, plant height, spike length and ear density over the two crop seasons, but not in days to heading, spikelets $spike^{-1}$, kernels $spike^{-1}$, grain yield and biomass yield. However, grain yield in 1999 and days to heading in 2000 were significant showing the effect of seasonal variation. Similarly, durum wheat varieties exhibited a significant difference ($P \leq 0.001$) for days to heading, number of tillers $plant^{-1}$, plant height and spike length and spike density. For grain yield, however, the significance was at $P \leq 0.05$. There was no significance difference among durum varieties for biomass yield and number of spikelets $spike^{-1}$. The variety × year interaction was significant for days to heading, plant height and number of spikelets $spike^{-1}$. The estimates of variance components revealed that the patterns of variation among bread (data not shown) durum wheat varieties and landraces were due to genotype differences than the effect of their collections sites (provinces, districts, etc.). This is not surprising given that most of the varieties grown were of recent introduction to the production sites.

Table 5. Simple Pearson correlation coefficient for bread wheat (matrix above diagonal) and durum wheat (matrix below diagonal) in Syria.

Agronomic characters	TIL	PH	DTH	GYD	BYD	SL	SN	NKS	ED
Tillers $plant^{-1}$ (TIL)	-	-0.34	0.68	-0.04	-0.18	-0.31	-0.17	-0.05	-0.06
Plant height (PH)	-0.10	-	-0.88^{*}	0.85^{*}	0.91^{*}	-0.03	0.00	0.05	0.74
Days to heading (DTH)	0.02	0.13	-	-0.71	-0.82^{*}	-0.25	-0.28	0.06	-0.47
Grain yield (GYD)	0.41^{*}	-0.49^{**}	0.26	-	0.98	-0.20	0.06	-0.41	0.65
Biomass yield (BYD)	0.58^{**}	-0.10	0.21	0.32	-	-0.07	0.14	-0.30	0.65
Spike length (SL)	0.27	-0.40^{*}	0.34	0.71^{**}	0.49^{**}	-	0.90	0.23	-0.62
Number of spiklets $spike^{-1}$ (SN)	-0.06	-0.50^{**}	-0.15	0.14	0.05	0.48^{**}	-	-0.19	-0.62
Number of kernels $spike^{-1}$ (NKS)	-0.08	-0.48^{**}	0.02	0.15	-0.13	0.05	0.30	1	0.12
Ear density (ED)	-0.32	0.15	-0.49^{**}	-0.72^{**}	-0.51^{**}	-0.84^{**}	0.07	0.12	-

Note: * and ** are significant at $P \leq 0.05$ level and $P \leq 0.01$, respectively.

Principal Component Analysis

In durum wheat a number of landraces collected from isolated sites from Aleppo and an adjacent province from Idelib were planted along modern varieties to study the pattern of agronomic and morphological variation. The principal component analysis showed that the first six principal components with eigenvalues of more than unity accounted for about 79% of the total variation among durum wheat varieties and landraces for the 23 agronomic and morphological traits studied. The first, second and third components (25.5, 22 and 11.5%, respectively) altogether accounted for a cumulative 52% of the variation. The first principal component was associated with important agronomic traits such as days to heading and grain yield and phenotypic traits such as beak length and cross section of the neck. The second component was associated with plant height and phenotypic traits such as flag leaf sheath glaucocity, glaucocity of the neck and ear color and the third with auricle color. The fourth component was associated with agronomic traits such as spike length and number of spikelets spike^{-1} and phenotypic characteristics such as awn and grain color. The number of tillers plant^{-1} and biological yield were associated with the fifth component whereas the sixth component was associated with phenotypic characteristics such as shoulder width and shape of the glume.

Figure 4 shows the distribution of durum wheat varieties and landraces along the first two axes of principal components. The durum wheat landraces such as Swadi collected from Aleppo and Idelib provinces occupied the right extreme of the first component with positive scores. The first component was able to separate the durum wheat varieties and landraces on agronomic traits such as days to heading and phenotypic traits such as awn color and glume color. Landraces with long days to maturity and with darker glumes and grain color occupied the positive scores whereas those with shorter days to maturity and light color occupied the negative scores of the first component. The second component was able to separate the modern wheat varieties from landraces based on plant height. Modern varieties usually with shorter plant height occupied the top extreme of the second component whereas landraces with long plant height occupied the lowest axis of the second principal component. The principal component analysis explained most of the variation that existed within durum wheat genotypes.

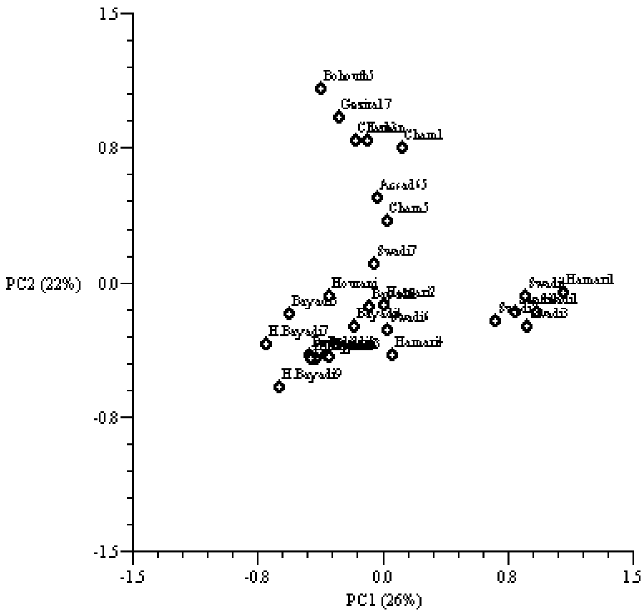

Figure 4. Principal component coordinate of durum wheat varieties and landraces from Syria.

Cluster Analysis

Hierarchical cluster analysis based on average values of 23 agronomic and phenotypic traits resulted in clustering the durum wheat varieties and landraces into two major clusters and four subclusters (Figure 5). The correlation between the cophenetic value matrix and actual matrix data was very high (0.79) indicating a very good fit of the cluster analysis performed. The Swadi landraces were distinct and form a separate subcluster particularly because of days to maturity and phenotypic characteristics as they all exhibited intermediate beak length, brush hair of grain and other glume characteristics. However, within the Swadi sub-cluster materials collected from Aleppo and Idelib were clustered separately. All modern durum wheat varieties (Acsad 65, Bohouth 5, Cham 1, Cham 3, Cham 5, Gezira 17 and Lahan) fall within the same subcluster mainly because of shorter plant height and high flag leaf sheath glaucocity (waxiness). These varieties were clustered within the Bayadi-Hourani subcluster probably because of their original breeding history where landraces were incorporated. Landraces such as Bayadi, Hamari and Hourani-Bayadi were clustered together showing some degree of similarity as compared to Swadi which was clustered separately. Moreover, Hamari1 collected from Aleppo clustered with Swadi from Aleppo instead of Hamari from Idelib. This may indicate the existence of distinct genotypes within local wheat populations. Hourani, a once popular durum wheat landrace, was clustered separately within the Bayadi-Hourani sub-cluster which probably shows its distinctive nature. Some farmers claimed that the seed for Hourani is usually sourced from southern Syria. The Hamari landraces were rather dispersed and clustered within two subclusters. The information generated in morphological traits diversity could be of interest to germplasm conservation or those whose interest is for identification of the varieties for seed certification purposes or intellectual property protection. The most important ones are agronomic traits diversity which could be of immediate use by the breeders. Earlier studies showed that Syrian durum landraces were diverse but also grouped with materials from other countries such as from Algeria, Greek and Tunisia (Impiglia et al., 1998).

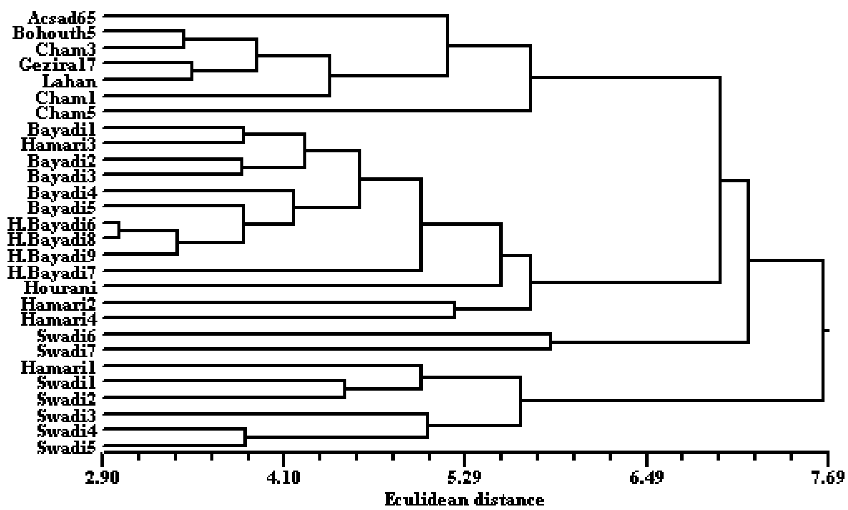

Figure 5. Dendrogram showing clustering of durum wheat varieties and landraces collected in Syria.

Spatial and Temporal Diversity of Barley Varieties

Arabi Aswad was the single most predominant barley landrace grown by sampled farmers over a four-year period in Aleppo, Raqqa and Hasakeh governorates of northeastern Syria. About 89, 94, 97 and 100% of farmers (n=200) planted barley in 1994, 1995, 1996 and 1997, respectively. Furat, a modern barley variety released by the national program, was planted by one farmer only (0.5%) and not widely adopted in the survey area. From 1981 to 1997 a total of seven modern barley varieties have been released by the national agricultural research system for use by farmers, an average of 3.5 and 0.4 varieties per decade or per year, respectively. Despite such long list of modern varieties released none of them were widely adopted; and possibly rejected because of farmers' preferences and lack of adaptability (Bishaw, 2004). There was no significant change in the pattern of varieties grown, area allocated for production and average yield of barley crop, although the trend appeared to be increasing. Barley is grown in areas with low annual rainfall having greater spatial and temporal variation in terms of the amount and distribution of rainfall (Ceccarelli et al., 1987). The majority of farmers surveyed grow barley continuously year after year with few exceptions where the crop is rotated with legumes (lentil, lathyrus) or the land is fallowed. There is a growing trend towards continuous barley cultivation instead of fallowing (Tutwiler et al., 1997) partly due to the availability of and use of fertilizers (Mazid, 1994).

The two distinct barley landraces, Arabi Abiad (white seeded) and Arabi Aswad (black seeded) are grown widely throughout the country. However, these landraces are cultivated entirely in two geographically different parts of the country. Arabi Abiad is mostly cultivated in western and northwestern parts of the country including the governorates of Aleppo, Hama, Homs and Idelib. These areas are relatively wetter compared to the interior and northeastern part of the country. Arabi Aswad is popular in northeastern part of the country where major production areas are located in Aleppo, Raqqa and Hassakeh governorates and where the barley seed supply study was carried out in 1997/98 crop season. The present expansion in barley production is taking place in this region where more marginal land is brought under cultivation. Arabi Aswad is adapted to relatively drier areas than Arabi Abiad and in most circumstances the majority of farmers grow a single landrace with low on-farm varietal diversity. The popularity of the black seeded barley in the dry environment could be due to their adaptation to the dry areas (Ceccarelli et al., 1987). In contrast, farmers in Ethiopia grow a large number of modern varieties (six) and landraces (fourteen) showing high diversity of barley crop (Woldeselassie, 1999). Accordingly, within each region, one landrace and one modern variety accounted for 60% of sample farmers in southeastern region whereas one landrace was planted by over a third of farmers (37%) in northwestern region. Cromwell and Tripp (1994) and Tripp (1997) also cited that as many as over 60 rice landraces have been recognized in a farming community in Sierra Leone and individual farmers grew a relatively large number of landraces (4-8) fitting to different micro-environments and household consumption needs. Sperling (1998) also cited from other sources that farmers in Rwanda grew bean mixtures of as many as 3 to 30 components with individual farmers growing two or three different varietal blends.

Empirical evidence shows that farming communities maintain many crops and varieties not for the sake of diversity *per se* but because of the multiple and diverse end uses. The need to use different crops or varieties for preparation of different foods or its cultural and aesthetic values could be the driving force for diversification of crops. In Syria, the primary use of barley is for livestock feed. The crop is grazed green or the grain and straw is used as livestock feed after harvest during the dry season. One may question why there is a need for farmers to keep the diversity of barley on the farm. Is there any feed quality trait of different barley landraces that improves the performance of the livestock? Is there any feed quality trait from different barley landraces that could improve the quality of the livestock products? Is there any agronomic quality trait of different barley landraces that matches with different soil types, rainfall patterns? After all, is there any outstanding demand or need to maintain diversity of the barley crop other than its agronomic performance in terms of more grain and biomass yields for the animal feed?

The on-farm spatial and temporal diversity of barley crop appeared to be limited in scope given the number of landraces grown and the area planted with each variety. However, barley is grown in the Fertile Crescent for millennia. And these barley landraces have been subjected to natural and human selection and found to be adapted to one of the harshest and stressful environments characterized by drought, cold, heat, salinity and therefore expected to have tremendous genetic diversity (Ceccarelli et al., 1987; van Leur et al., 1989). According to Ceccarelli et al. (1987) the presence of different genotypes within the barley landraces or populations conditioned them to cope with different stresses of different magnitude in achieving yield stability in harsh environments. Such latent diversity could only become apparent when new plant diseases and pests or environmental changes challenge these landraces. In Syria, participatory plant breeding has been initiated in barley as a means of identifying new varieties that match farmers' preferences. Adoption of such varieties by farmers would be expected to increase on-farm varietal diversity if new varieties occupy specific niches in the diverse farming system. This would increase overall production as each niche becomes occupied increasingly by the best-adapted new variety.

Barley Traits Diversity

About 50 barley seed samples collected from farmers representing 25 villages were planted at two sites. Table 6 presents the mean, minimum, maximum values and standard error of mean of six agronomic characters measured during the field experiments showing greater variability. The mean time to flowering was rather stable with an average of 103 days although some genotypes showed a potential of early flowering under both environments. The mean spike length was 7.4 cm with a range from 4.9 cm to 9.9 cm whereas the average number of kernels spike^{-1} was 20.4 seeds with a range of 14.9 to 26.4 seeds showing greater variation within the genotypes. Moreover, the landraces showed greater variability and yield plasticity ranging from 630 to 3410 kg ha^{-1}. Ceccarelli et al. (1987) did not find a large variation, though significant, between collection sites for both days to heading and days to maturity among barley landraces collected from Syria and Jordan. They also found variation among the genotypes for spike length and grain yield and these characters were found most associated with each other within and between different collection sites. On the other hand the number of tillers per plant and ear density showed lesser variability.

Table 6. Mean, minimum, maximum and standard error of mean of agronomic traits for barley genotypes in Syria.

Agronomic characters	Breda	Tel-Hadya	Breda and Tel Hadya		
			Minimum	Maximum	Mean ± SE
Days to flowering (d)	103.7	103.1	100	108	103.4 ± 0.1
Number of tillers plant^{-1}	0.79	1.43	0.26	3.04	1.12 ± 0.03
Spike length (cm)	6.23	8.37	4.94	9.92	7.31 ± 0.09
Number of kernels spike^{-1}	18.1	22.7	14.9	26.4	20.4 ± 0.19
Ear density (ratio)	2.91	2.70	2.35	3.39	2.80 ± 0.01
Grain yield (kg ha^{-1})	1030	2150	625	3405	1592 ± 49

The barley genotypes responded differently in terms of agronomic performance in the two environments when grown at Breda and Tel Hadya showing the effect of genotype by environment interaction and the possibility of yield improvement through selection. All genotypes responded positively to the Tel Hadya environment where relatively more tillers plant^{-1}, greater spike length, more kernels spike^{-1} and a higher grain yield were recorded than in Breda. The days to flowering appeared to be similar in both locations. The materials were planted slightly later than the recommended date of planting for barley which may have affected days to flowering.

Variance Component Analysis

Variance component analysis was done to measure the significance and contribution of sources of collection (provinces, districts and collection sites) on variability in agronomic characters of barley landraces. There was a significant difference among genotypes for days to flowering, number of tillers plant^{-1} and number of kernels spike^{-1} across the two locations (Table 7). Significant difference was observed for days to flowering for genotypes collected from different districts, although not significant at each growing site. Moreover, barley genotypes collected from different provinces showed significant differences for spike length and number of kernels spike^{-1}. Ceccarelli et al. (1987) also found significant difference for spike length among barley genotypes both between and within collection sites. The estimates of variance components of collection sites to variation in barley landraces were found to be minimal (data not shown). The highest contribution was observed for the number of tillers plant^{-1}, followed by grain yield and number of grains spike^{-1}.

Principal Component Analysis

The variance component analysis revealed limited information on source of variation among barley genotypes and the effects of collection sites on their agronomic performance. A principal component analysis was made using a correlation matrix to define the patterns of variation both between barley genotypes and between their regions of origin. The principal component analysis showed that the first three components with eigenvalues greater than unity accounted for about 74% of the total variation among 50 barley landraces for the 6 quantitative traits (tillers plant^{-1}, days to flowering, grain yield, spike length, number of kernels spike^{-1} and ear density) studied (data not shown). The first, second and third components accounted for 33, 23 and 18% of the total variation, respectively. The most important characters of the first component were spike length and the number of kernels spike^{-1}, important agronomic traits for yield of the barley crop. The number of grains spike^{-1} and ear density (the ratio of number of grains to the spike length) was an important character for the second component. Days to flowering and grain yield were important characteristics for the third component.

To study the regional pattern of variation principal component analysis was further made using the means of collections sites (villages) for the six quantitative characteristics. The first two principal components with eigenvalues above unity accounted for 59% of the variations. Figure 6 gives the relationship of the barley genotypes based on the first two axes of the principal components. The two principal components were able to separate the barley genotypes collected from different villages almost equally, although the separation did not follow the geographical patterns. The barley genotypes collected from the Aleppo province were almost found in all four quadrants compared to samples collected from Hasakeh and Raqqa provinces. Some barley genotypes collected from Aleppo appeared to occupy the extremes of first principal component axis (positive scores) and the second principal axis (positive and negative scores). Apparently the first principal component differentiated the barley genotypes on spike length and the number of kernels spike^{-1}. Genotypes with high scores for these characters were on the left side from the origin whereas those with low values are on the right side. The second principal component was able to separate genotypes based on the days to flowering and ear density. Moving towards the bottom of the axis of the second component we find genotypes with longer days to flowering whereas the opposite was true for genotypes with shorter days to flowering. The materials from Hasakeh and Raqqa provinces had a tendency of occupying the middle of the two principal components with few exceptions. The results may indicate that the materials from Aleppo province are more diverse compared to the materials collected from Hasakeh and Raqqa provinces.

Table 7. Significance (P) level for comparison of barley landraces and their partitioning into sources of collection in Syria.

	Tillers plant^{-1}	Days to flowering	Grain yield	Spike length	Kernels spike^{-1}	Ear density
Genotypes	0.03	≤0.001	0.81	0.24	0.03	≤0.001
Location × Genotypes	0.332	≤0.001	0.888	0.071	0.254	0.010
Province	0.496	≤0.001	0.841	0.004	0.022	0.173
District	≤0.001	≤0.003	0.581	0.880	0.296	0.130
Sub-district	0.299	0.054	0.642	0.459	0.253	0.391
Village	0.774	≤0.001	0.973	0.660	0.129	0.14
Farmer	0.125	≤0.001	0.315	0.304	0.215	0.015
Location × Province	0.226	0.191	0.911	0.244	0.141	0.300
Location × District	0.091	0.027	0.857	0.224	0.059	0.424
Location × Sub-district	0.228	≤0.001	0.544	0.255	0.410	0.686
Location × Village	0.477	≤0.001	0.980	0.960	0.913	0.179
Location × Farmer	0.645	≤0.001	0.380	0.016	0.147	0.002

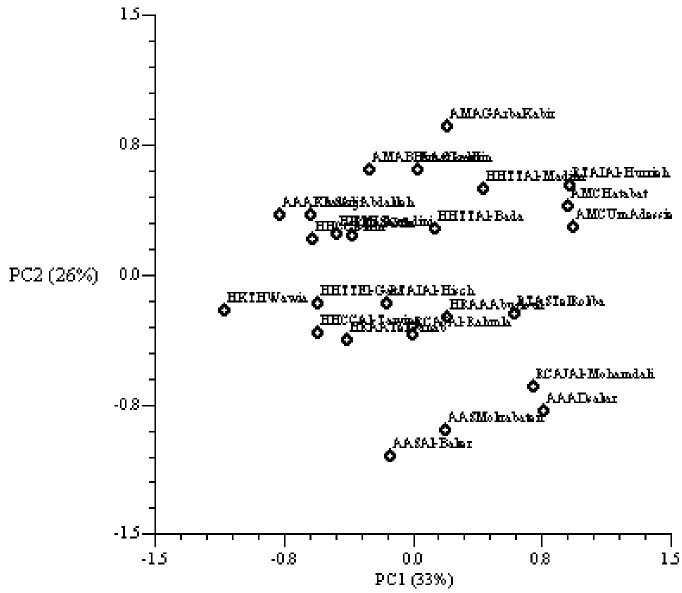

Figure 6. Principal component plot of barley genotypes based on mean of collection sites (villages) for six quantitative characteristics.

Cluster Analysis

Figure 7 presents a clustering of barley genotypes based on six quantitative traits averaged over two locations. Clustering resulted in grouping the 50 barley genotypes into two major clusters and six subclusters each varying from 2 in the smallest to up to 15 in the broadest classes. The first cluster consists of two barley genotypes (AASE29 and AASE42) both collected from Manbeji in Aleppo province clustered separately from the rest of the landraces; and they were low yielding among the whole genotypes. In Subcluster 1, barley genotypes such as AMAG59, RTAS124 and HHCC192, all three from different provinces, were grouped together based on the tillering capacity, the highest being exhibited by RTAS124 collected from Raqqa. In Subcluster 2, genotypes such as AAEA4, AASE28, AASE30, AASE38, HKTH151 (from Hasakeh) were clustered together. The materials in Subclusters 1 and 2 had more tillers plant^{-1} and slightly more kernels spike^{-1} compared to materials from other sites. AMC66, AMC 77, HHTT182 along AAEA 2, HRAA169 AND HHTT157 were grouped under one subcluster (6) and they exhibited high yield compared to other genotypes. The genotypes within the clusters did not cluster according to the geographic origin of collection sites. There was no clear cut clustering as genotypes from different zones, provinces, districts and villages were clustered together. At least two barley genotypes collected from the three provinces were present in all subclusters showing limited differentiation among the genotypes to their region of origin. For example, barley materials collected from Aleppo province in Zone 2 (AAEA2) were clustered along with genotypes collected from Hasakeh in Zone 3 (HHTT157 and HRAA169). Likewise most of the barley genotypes collected from the same province, district and sub district, but adjacent villages were not exactly clustered together. Two barley landrace samples collected from Zone 4 in Raqqa (RCAJ95 and RCAJ105) were not clustered with each other or with samples collected from Zone 4 in Haaskeh. However, one interesting feature observed was that most samples from different provinces, but adjacent districts were grouped together under one subcluster.

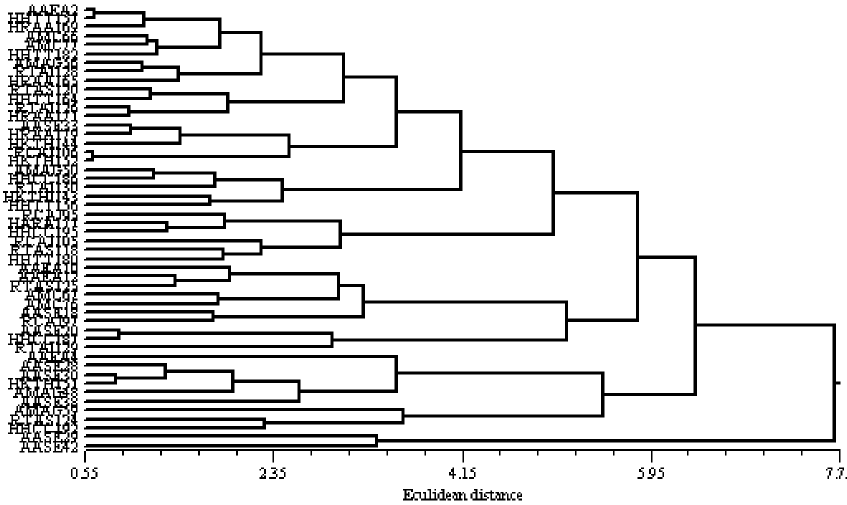

Figure 7. Dendrogram showing the clustering of fifty barley genotypes collected from Syria based on six agronomic characters (A=Aleppo, R= Raqqa and H= Hasakeh).

Clustering did not differentiate barley genotypes from different collection sites in Syria into the regions of geographic origin. Such lack of strong regional differentiation observed by the cluster analysis could be partly from seed flow between regions. It was reported that most of the barley seed was obtained through informal sources where exchange of seed took place among farmers or from traders over long distances particularly bringing seed from nearby provinces and districts (Bishaw, 2004). During the field survey some farmers reported having purchased barley seed for planting from a nearby province or district instead of their hometown. Accordingly this reflects the movement of barley landraces across regions and production zones. The informal exchange of barley seeds among regions could be one of the reasons for such lack of clarity on the clustering of genotypes to specific regions of origin.

The lack of clear-cut variability indicators among barley genotypes collected from different parts of the country is surprising given earlier studies by Ceccarelli et al. (1987). There could be five possible points contributing to this limited variation among the genotypes as well as the effect of collection sites. First, the number of agronomic characters used for the experiment was small with anticipation of greater variability among the landraces which happen to be not the case. Second, the barley materials collected were not come from distant places, but rather within contiguous or adjacent provinces and districts where a continuous sampling would create a morphological continuity compared to materials in previous studies selected from geographically distant regions. Third, barley seed samples were collected from farmers compared to earlier collection where ears were sampled from the growing crops. Fourth, the materials used for study were all black seeded landraces and did not contain any white seeded barley. Fifth, the General Organization for Seed Multiplication was involved in seed supply of barley landraces in Syria particularly prior to 1991 where demand for barley seed was high because of subsidized price. Such large-scale seed multiplication and distribution of landraces may contribute to the narrowing of previously existing variability in the field. In general, these findings should be interpreted with great caution. It is worthwhile, however, to undertake further genetic diversity studies to observe the changes in the genetic structures of barley landraces currently grown using both morphological and molecular characters and compare them to earlier results to substantiate these findings. This would assist in studying the genetic and population shifts of landraces and populations with the introduction of commercial agriculture.

In summary, the Syrian national agricultural research system in collaboration with the International Center for Agricultural Research in Dry Areas (ICARDA) made a spectacular success story in developing varieties that are adapted to stress environments and at the same time responsive to better management practices (Mazid et al., 2003). The government policy support coupled with availability of modern varieties and adequate infrastructure in irrigation facilities makes Syria become self-sufficient in wheat production. With the continuous integration of Syrian farmers to commercial crop production and marketing and the changing food habits of rural population the landraces would be the losers. This success story is not without cost where large areas previously grown to traditional varieties and landraces are now completely replaced by contiguous expanse of land planted to uniform modern bread and durum wheat varieties. Moreover, some of these modern varieties are grown by large number of farmers. Apart from the landraces, the wild relatives and progenitors of both wheat and barley are being threatened by extinction.

While we are ‘baffled’ by the very rapid disappearance of the durum landraces the persistence of a couple of traditional barley varieties throughout the country remains a mystery. Earlier we found that one third of the farmers saw no disadvantage of the Arab Aswad and at least for the time being had shown little intention to replace them with other modern varieties; and the majority of farmers were satisfied with grain yield, grain size, grain color, feed quality and marketability of the landrace (Bishaw, 2004). ICARDA barley breeders are still grappling with methodological approaches for barley improvement to diversify the portfolio of varieties available to farmers through scientific plant breeding and very recently with some participatory flavor. Crop diversity is a dynamic process managed by farmers involving the introduction and incorporation of new crops or varieties or a withdrawal of existing crops or varieties to adapt to the technological and environmental changes (Bellon, 1996). It would be interesting to understand the persistence of the traditional barley varieties through a methodological approach of social science than a mere biological approach alone.

Conclusions

Syria is the center of origin and domestication for tetraploid wheat and barley where a considerable wealth of genetic variability and diversity still exists on the farm. The complex, risky and dry areas of Syria coupled with a long history of association with the crop under a variety of socio-economic and cultural situations led to the evolution of highly diverse forms of these crops. Until recently this wealth of genetic diversity has been maintained by generation of farmers. However, the introduction of modern agriculture brought a dramatic shift in wheat production practices. Since the mid-1990s, almost all wheat production areas are covered by modern varieties in Syria. Few landraces are grown on small areas in very isolated pockets and remote areas by the smallholder farmers despite their preferences for preparing traditional foods. The wide spread adoption and diffusion of modern bread and durum wheat could led to the complete replacement of these valuable genetic resources - the loss of durum landraces. The loss of landraces also leads to loss of local knowledge in crop improvement and maintenance. It is important to design an innovative and integrated genetic resources conservation, maintenance, enhancement and utilization strategies and approaches that could meet the aspiration and food security of the majority of farmers that depend for their livelihood on these crops. It is desirable that the participation of national governments and all stakeholders in formulating and targeting the interventions required.

The national agricultural research systems made a spectacular progress and achievement in developing modern varieties of bread wheat and durum wheat that meets farmers' preferences. In contrast, there is little headway in crops like barley where landraces still dominate the agricultural landscape. Not only lack of success in developing modern varieties, but also farmers rejected those varieties released by the national programs and the area under improved varieties is negligible. The marginal barley production areas of Syria had high spatial and temporal variation in terms of temperature and rainfall. In apparent effort to circumvent the failure of conventional crop improvement program alternative breeding strategies have been initiated for many crops in marginal areas with or without farmer participation. PPB had been initiated for barley and preliminary results were promising. Therefore, NARS should introduce and institutionalize participatory approaches (PVS and/or PPB) as a means of identifying new varieties that farmers prefer and link this with formal plant breeding and seed production activities. Adoption of such varieties by farmers not only enhances productivity but also maintains and improves on-farm varietal diversity of durum wheat and barley crops.

The agronomic and phenotypic studies revealed a wide range of variation for each of the traits studied particularly among the modern bread wheat varieties that will provide farmers an opportunity to make a choice of genotypes that will fit best to their niche environments. Moreover, the variation that exists among the landraces offers broad opportunities for using the genotypes with desired agronomic characters in the plant breeding program to develop varieties suitable for different agro-ecological zones of the country. In Ethiopia, past effort to use exotic germplasm in developing durum wheat varieties with wider adaptation to the local conditions met with little success and the locally adapted germplasm remains under exploited in the national breeding program. Therefore, the national agricultural research system should incorporate the landraces into their breeding program and develop location specific varieties that meet farmers' requirements and also increase on-farm diversity.

The spatial diversity, temporal diversity, coefficient of parentage analysis and measurements of agronomic and morphological traits were employed to explain the diversity of wheat and barley varieties or landraces grown by farmers in Ethiopia and Syria. While the spatial diversity and temporal diversity indicates the domination of few selected varieties in terms of area coverage the agronomic and phenotypic measurements showed the remarkable variation that existed both among modern varieties and landraces that would provide broader opportunities for use in crop production or crop improvement. Since different measurements and scales were used to define diversity it would be difficult to ascertain a set of common indicators and their interrelationships that would satisfy both the biological scientists and social scientists concerned with biodiversity issues. It is imperative that a multidisciplinary approach is undertaken to address the problem and develop a common framework for assessing genetic diversity that would enable policy changes required to enhance the conservation and utilization of these resources to the benefit of farmers and the society at large.

This study was not meant to measure wheat and barley diversity *per se* or intended to investigate the patterns of diversity from the geographic or agro-ecological context. It was rather an attempt to look into the agronomic and morphological traits diversity of sets of varieties currently used by farmers and any specific traits that are associated with farmers' considerations or preferences for particular group of varieties or landraces. For example, one clear example is farmers' demand for black seeded barley varieties in drier areas of Syria. Black seed color in barley is associated with drought tolerance, vigorous early growth, taller plants and early maturity all which are important agronomic characters for dry areas. These are some of the agronomic characters Syrian barley farmers are exactly seeking from new varieties that would replace the landraces currently grown widely throughout the country.

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