

**Farmer Participation and
Use of Local Knowledge
in Breeding Barley
for Specific Adaptation**

GTZ Project No. 95.7860.0-001.13

ANNUAL REPORT 1997



The International Center for Agricultural Research in the Dry Areas (ICARDA)
P.O. Box 5466, Aleppo, Syria

Part I. PROJECT SUMMARY

Title: Farmer Participation and Use of Local Knowledge in Breeding Barley for Specific Adaptation

Objectives of research

1. Improved barley varieties that fulfill the needs and objectives of poor farmers in the marginal rainfed environments.
2. Enhanced rate of adoption of new varieties through farmers' participation in selection and testing.
3. A participatory approach to breeding barley for stress conditions.

Abstract: Breeding philosophies and methodologies developed for favorable conditions and high input agriculture have been ineffective in generating improved cultivars for marginal conditions and low input agriculture. The proposed program will develop and implement a novel breeding approach for barley improvement in low potential, marginal rainfall environments of northern Syria based on: (a) early selection and testing under real farmer conditions, (b) use of farmers' selection criteria, (c) use of market derived economic criteria during both selection and testing, and (d) validation and quantification of grain and straw qualities used as selection criteria. The research will utilize the subjective assessments of producers and consumers to establish objective indicators of crop quality.

The expected outputs include increased adoption of new varieties in low-input agriculture and crop quality indicators which are appropriate to the needs of producers and consumers. The new breeding program, targeted at marginal conditions and low-input agriculture, will move selection and testing work outside experiment stations and put breeding into the hands of farmers. We expect that, even in a relatively small geographical area, farmers will tend to exploit specific adaptation. Specific adaptation benefits biodiversity through selection and spreading of a number of different cultivars, instead of the few, often closely related, cultivars characteristic of conventional breeding for wide adaptation.

IARC programme and unit: Germplasm Enhancement and Breeding: Project 4. Spring Barley, within the Germplasm Program of ICARDA

IARC project coordinator: Dr. Salvatore Ceccarelli, Barley Breeder and Acting Leader, Germplasm Program

Collaborating institutions: Institut für Agrar- und Sozialökonomie in den Tropen und Subtropen, University of Hohenheim, Germany
Agricultural Research Center, Ministry of Agriculture and Agrarian Reform, Syria

Project scientists (financed): Proportional time commitment of senior ICARDA staff
One National professional Officer, ICARDA
One Ph.D. student, University of Hohenheim
Research Technician at ICARDA

Project duration: January 1, 1996 to December 31, 1998

<i>Budget summary (in DM):</i>	<u>Year 1</u>	<u>Year 2</u>	<u>Year 3</u>	<u>Total</u>
ICARDA	244,500	208,000	129,000	581,500
Hohenheim	<u>45,200</u>	<u>35,600</u>	<u>0</u>	<u>80,800</u>
TOTAL	289,700	243,600	129,000	662,300

Part II. ANALYTICAL SUMMARY

1. Identifying information

Project No.: 95.7860.0-001.13	Date:
Title: Farmer Participation and Use of Local Knowledge in Breeding Barley for Specific Adaptation	Reporting period: January-December 1997
Reporter: Dr. S. Ceccarelli, Acting Program Leader and Barley Breeder, Germplasm Enhancement Program, ICARDA, Project Coordinator	Address: ICARDA, P.O. Box 5466, Aleppo (Syria) Tel: +963 21 225112 Fax: +963 21 213490

2. Project Characterization

Characteristics of research	Increase in Productivity	Environmental Protection	Safeguarding of biodiversity	Policy, Socio economic Research	Consolidation of National Programmes
Basic + Strategic	60	20	60	80	50
Adaptive-on Farm	25	80	30		
Networking					
Training	10		10	20	50
Information	5				
Other					
	100	100	100	100	100

3. Achievements and Constraints

The major achievements during the reporting period were:

1. Formulation of a Hedonic Price Model explaining 86% of the variability in barley prices in the Aleppo Market
2. Progress in the preparation of survey data for statistical and econometric analysis
3. Completed the first cycle of farmers' selection (both individual and by group of farmers) as well as the first cycle of breeder selection. The major indications of this first cycle of selection are:
 - a) that farmers have no difficulties in handling a large population of different types;
 - b) that farmers are able to develop their own scoring methods and can score a number of traits during the cropping season;
 - c) that when highly contrasting types of germplasm, such as landraces and improved, are utilized, selection seems to be mainly environmentally driven;
 - d) that there is very little similarity between selections made by different farmers in different environments and between farmers and breeders;
4. Dissemination of the methodology among NARS: four scientists from Jordan, one from Tunisia and one from Morocco participated in some of the field activities together with the participating farmers.

The major constraints are those derived from the unfavorable exchange rate.

4. Implication from Current Reporting Period.

Given the interest that the project has generated among scientists in other national programs, it would be highly desirable to add the following activities during 1998:

1. A visit of barley breeders from 20 different countries (Morocco, Algeria, Tunisia, Libya, Egypt, Yemen, Ethiopia, Eritrea, Iraq, Iran, Jordan, Pakistan, Nepal, India, China, Ecuador, Peru, Bolivia, Colombia and Mexico) during the period of group selection with farmers. It would be highly desirable that a GTZ representative could visit the project at that time;
2. Study the methodological changes needed to apply the knowledge generated by this project to different areas where farm size is very small, such as the terrace-agriculture typical of Nepal, Tigray, Eritrea and Yemen. It would be highly desirable to invite a consultant to visit the project and to develop such a methodology.

These two additional activities could be covered partly with funds from other special projects, partly with core funds and partly with savings from the cropping season 1996/97.

5. Communication and Dissemination of Information

Dr. S. Ceccarelli attended a Workshop "Ethical and Equity Issues in the Conservation and Use of Genetic Resources for Sustainable Food Security - Developing Guidelines for the CGIAR". He presented a paper "Increasing the Efficiency of Breeding through Farmer Participation", co-authored by Dr. S. Grando. A lecture was given by S. Ceccarelli at senior students and staff of the college of Agriculture of Asmara University in Eritrea on participatory plant breeding. The

relationships between selection for specific adaptation, decentralization and participatory plant breeding were discussed with the crop breeders of AREA (Agricultural Research and Extension Authority) in Yemen. Eventually the project has been used as a basis to develop a similar project in Tunisia and Morocco, supported by IDRC.

6. Status of Work Programme

	Work Plan for current reporting period	Work Plan for next reporting period	Remarks
Work Programme	Jan 01 - Dec 31, 1997	Jan 01 - Dec 31, 1998	
Component 1	a) identification of groups of farmers b) group selection performed		Concluded
Component 2 Output 1	a) observation and analysis of farmers' selection criteria b) relationship between farmers' selection criteria and objective measurements of plant characteristics	a) observation and analysis of farmers' selection criteria b) relationship between the two selection cycles	Continuing
Component 2 Output 2	a) desirable characteristics verified during selection both by individual farmers and farmers' groups b) one or more validated lists of desirable characteristics	a) desirable characteristics verified during selection both by individual farmers and farmers' groups b) one or more validated lists of desirable characteristics	Continuing
Component 2 Output 3	a) observation and analysis of perception of g x e interaction by comparing lines selected in different environments	a) observation and analysis of perception of g x e interaction by comparing lines selected in different environments	Continuing
Component 3	a) complete analysis to refine model b) a model explaining more than 60% of the variability of barley price	a) validation of the model	
Component 4	a) selection by farmers and breeders in farmers fields and in the experiment stations b) lines selected by farmers and breeders	a) selection by farmers and breeders in farmers fields and in the experiment stations b) lines selected by farmers and breeders	
Component 5	a) analysis of straw and grain quality on each of the 208 lines in the nine locations b) relationships between quality parameter and farmers' selections	a) multiplication of the most promising lines for feeding trials b) analysis of data on straw and grain quality on each of the 208 lines in 1997/98 season and correlation with farmers and breeder selection	

7. Status of Funding

Please refer to Financial Report submitted separately.

Part III. SCIENTIFIC SUMMARY

COMPONENT 2: INDIGENOUS KNOWLEDGE

COMPONENT 3: MARKET STUDY

The main activities under this Component were:

1. Statistical and econometrical analysis of quality data which were generated in the ICARDA-PFLP laboratory by NIRS estimation of 438 barley samples and by chemical analysis of a subset of 100 barley samples¹
2. Repetition of the chemical analysis for the subset of 100 barley samples
3. Statistical and econometrical analysis of re-measured data and formulation of a hedonic pricing model for the Aleppo market
4. Preparation of farm survey data for econometric analysis²

3.1 Results

Statistical and econometrical analysis of quality data

Two files with laboratory data of barley quality have been received from ICARDA: File 1 contains NIRS estimates of crude protein, acid detergent fibre and seed colour for the entire set of barley samples (n=438). File 2 contains data of chemically analysed crude protein and acid detergent fibre as well as of physically determined kernel weight, seed colour and non grain components. Corresponding market prices had been collected in line with each of the 438 samples during the 1995 post harvest season in three major barley markets of northern Syria.

¹ Barley samples, were collected during 1995 in three wholesale barley markets of northern Syria.

² The farm survey was conducted in 1995 and included structured interviews with 247 farmers in northern Syria.

In order to explain price as a function of the various quality variables multiple regression analysis was done, based on the above described data. Prior to Hedonic Price Analysis hypotheses concerning the direction of influence of the explanatory quality variables on market price were formulated. Expected signs of the parameter coefficients are given in Table 1.

Table 1. Expected signs of parameter coefficients.

Variable	expected sign of coefficient
Kernel weight	+
Crude Protein	+
Awns	-/+
empty seeds, stalks, moldy seeds	-
durum, lentil	+/-
other non grain components (soil, weed)	-
ADF	+/-
white colour (abiad)	-
grey colour (aswad)	+/-
black colour (abrush)	+

A first set of multiple regression equations was estimated with data from file 1 (n=438), the NIRS estimations. All variables were transformed to eliminate time trend effects on quality and price. Multiple Regression was done with SPSS version 6.01, using the backward method. Linear, semi-logarithmic and logarithmic models were calculated with transformed and untransformed values. However, the highest coefficient of determination arrived at 0,1. This indicates that only 10% of the variation in price could be explained by NIRS estimated quality parameters.

In order to get an idea of the goodness of NIRS estimations, coefficients of determination between the results of chemical analysis (data file 2) and the corresponding NIRS estimates (data file 1) were calculated for the variables \square adf \square , \square crude protein, and \square seed colour \square . Coefficients of determination range between 0,4 for adf and 0,7 for crude protein in the entire data file 2 (Table 2). This implies, that only 30% of the adf content and 70% of the protein content determined by chemical analysis can be explained by NIRS spectra. Thus, the percentage of unexplained variation of the NIRS estimates is quite high.

Table 2. Coefficients of determination for variables estimated by NIRS and determined by chemical analysis

data set	ADF	ADFaf	CP	colblack	colgrey
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all (104)	0.425	0.462	0.760	0.613	0.700
alp (39)	0.569	0.643	0.562	0.323	0.465
hm (33)	0.381	0.422	0.910	0.866	0.724
hsk (32)	n.s	n.s.	0.819	0.437	n.s.

A second set of multiple regressions was calculated based on data file 2, the results of chemical analysis. All regressions yielded better results than the multiple regression based on the NIRS estimates. Coefficients of determination for the variability in price was 0,376 (see Table 3). However, the results are still unsatisfactory as many of the significant coefficients in the models appear with unexpected and unexplainable signs. The most striking one was the positive sign for the coefficient of □sample contamination with soil□ (ssoil), which signifies that market prices increase with increasing soil content of the barley sample and is in total contradiction to results of empirical surveys conducted in 1995.

An examination of the coefficients of correlation between the variables □contamination with soil□ and □weed seeds□ and the variables □kernel weight□, □protein□ and □fibre content□, showed highly significant correlations in the range of 0,3 to 0,6. This result can neither be explained by theoretical considerations nor by empirical observations. Possibly, it is due to biased laboratory analysis. Therefore, barley samples contaminated with soil and moldy seeds were excluded from multiple regression analysis and a third set of models was estimated. The results given in Table 4 show a considerable improvement of the coefficient of determination as well as the expected signs for the coefficients of the explanatory variables. However, the results are not consistent with the preliminary hedonic price model which had been formulated in 1996. Especially the lack of influence of kernel weight and crude protein on market price of barley are not corresponding to initial hypotheses based on empirical observations as well as on economic theory.

Table 3. Results of set II of multiple regression estimates. Signs of coefficients and significance of t-values are shown.

Set 2	Aleppo		Hama		Hassakeh	
	sign coeff.	sig.	sign coeff.	sig.	sign coeff.	sig.
ADF						
ADFashf			-	0.0349	+	0.0256
ADL						
CP						
400kw	-	0.0371				
AwnG	-	0.0117	+	0.0228		
AwnL	-	0.24			-	0.0012
AwnLG						
AwnRG	+	0.0233				
AwnS	+	0.0083				

ScIB	+	0.0443		
ScIGR	+	0.0669		
ScLOW	+	0.06	+	0.2525
ScIW	+	0.0525		
Sbrkn			-	0.0197
Sdur				
Shull			-	0.0137
Slen				
Smold			-	0.0773
Sother			-	0.2151
Ssoil	+	0.0787		
Swed				
clmkt				
adj. R2 V		0.3250	0.3870	0.4540
n		39	34	34

Repetition of the chemical analysis for the subset of 100 barley samples

The same set of barley samples which had been used for data creation of file 2 was again analysed by employing corresponding methods for chemical and physical analysis. Prior to analysing, all the samples were cleaned from non-grain components and awns. Kernel weight was determined by measuring the weight of 200 kernels in three repetitions. Seed colour was determined by measuring the percentage of weight of grey, black and white seeds. Barley samples were ground using a 1 mm grid and were then analysed for crude protein, adf and dry matter in the Landesuntersuchungsund Forschungsanstalt (LUFÄ) of Baden-Württemberg.³

Statistical and econometrical analysis of remeasured data and formulation of a hedonic pricing model for the Aleppo market

Based on data from these analyses the forth an final set of multiple regression models for Hedonic Analysis is presently being estimated. To this point, only data from Aleppo market could be analysed. The other markets will be included later. Seasonal influence was eliminated using two alternatively applicable methods: a time dummy and transformation of variables according to a seasonal reference point. The variables of continuously measured non grain components were transformed into dummy variables describing the absence or presence of these components. An additional dummy was introduced for white barley samples. The final model explains 86% of the variability in price by the variables kernel weight, protein, dry matter, loose awns in the sample, white samples and season (Table 5).

³ Please see Appendix for results of new analyses.

Table 4. Results of set III of multiple regression estimates. Signs of coefficients and significance of t-values are shown.

Set III	Aleppo		Hama		Hassakeh	
	sign coeff.	sig.	sign coeff.	sig.	sign coeff.	sig.
ADF	-	0.0635	-	0.1234		
ADFashf					-	0.0888
ADL						
CP						
400kw						
AwnG						
AwnL	-	0.0037			-	0.0055
AwnLG						
AwnRG			+	0.3004		
AwnS						
ScIB						
ScIGR						
ScLOW						
ScIW	-	0.0185				
Sbrkn	-	0.0863			-	0.0338
Sdur						
Shull			-	0.0603		
Slen						
Smold						
Sother						
Ssoil						
Swed						
adj. R2		0.592		0.362		0.354
n		17		21		25

The contribution of the quality variables versus time to the explanatory power of the model was tested by observing the change of R^2 when the model was calculated with variables which had been transformed to eliminate time trend effects. Table 6 shows that 50% of price variability can be explained exclusively by quality characteristics of the barley samples.

Table 5. Results of formulated Hedonic Price Model.

Set IV	DF	F-value	sig.F	R2	variables	coeff.	t-value	sign of t
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Statistics:

32	29	0.0000	0.86	constant	19.20	3.5	0.0018
				dtmrkt	0.28	8.3	0.0000
				DAwnL	0.09	3.18	0.0039
				Dwhite	-0.13	-3.63	0.0013
				CP	0.03	3.1	0.0047
				KW	0.63	3.4	0.0023
				KW2	-0.02	-3.3	0.0027
				TS	-0.19	-2.9	0.0068

Table 6. Contribution of quality variables to the explanatory power of the model.

Set IV	Statistics				transf.	Statistics		
	DF	F-value	sig.F	R2	variables	coeff.	t-value	sig. t
	32	6.18	0.0004	0.49	constant	262.72	3.12	0.0043
					dtmrkt	skipped		
					DAwnL	1.51	3.46	0.0019
					Dwhite	-1.82	-3.28	0.0029
					CP	0.48	3.22	0.0035
					KW	8.63	3.04	0.0053
					KW2	-0.29	-2.90	0.0066
					TS	-2.33	-2.61	0.0151

All coefficients in the model have the expected sign and moreover the model corresponds to the result of previous hedonic price analysis conducted in 1996 with samples from 1995⁴. The decrease in the coefficient of determination from .60 in the 1996 model to .50 in the present

⁴ Please see annex and the annual report of 1996

model, is probably due to the fact that the variable "grinding resistance" was not determined for the data used in the 1997 model.

Especially interesting is the fact that kernel weight appears as a quadratic term in the model. This signifies that if kernel weight increases beyond an optimal level, the influence on price will be negative. This finding is consistent with empirical results. During the 1996 survey of market days in Aleppo it was often observed that samples with very high kernel weight yielded lower prices than samples with medium kernel weight. A reason for these findings is the negative correlation between kernel weight and protein, which is due to physiological mechanisms in cereal crops. The question is however why in the 1996 model the relationship between price and kernel weight was linear while it was quadratic in the actual model. A possible reason is that the average kernel weight of the barley samples for the 1997 model was about 10% higher compared to the barley samples which were collected for the 1996 model.

3.5 Conclusion and Relevance of the Results for the Overall Project Objective

The results demonstrate that the hedonic price analysis can indeed serve as a very helpful tool for genotype selection with participatory background. This was especially shown by the fact that variables included in models of different cropping years were consistent, although rainfall conditions were considerably different. The parameter coefficients show the marginal willingness to pay for one more unit of the respective characteristic. As the model has been formulated based on prices reflecting market demand and based on barley samples reflecting supply, we can conclude that the coefficients are representative indicators of farmers' preferences as well as of the economic utility for each barley quality characteristic. Provided that the model turns out to be consistent for a larger number of samples, it establishes a valuable and easy-to-handle tool for variety selection for quality which is based on farmers' demand.

COMPONENT 4: PARTICIPATORY BREEDING

4.1 Methods and General Information

As indicated in the 1996 report, 208 lines and populations were planted in November 1996 in nine farmers' fields and in three research stations (Tel Hadya, Breda and Bouider).

The barley populations planted in each village include:

50 high yielding lines unrelated to Syrian landraces (25 six-row and 25 two-row);

- 50 segregating populations from crosses between high yielding lines unrelated to Syrian landraces (25 six-row and 25 two-row);
- 50 lines derived from Syrian landraces (25 with black seed and 25 with white seed);
- 50 segregating populations from crosses with Syrian landraces (25 with black seed and 25 with white seed);
- 8 farmers' cultivars (from seed purchased from each of the eight original farmers).

The first 100 populations will be referred to as "improved", while the last three groups (a total of 108 populations) will be referred to as "landraces".

Table 7. Fertilizer application (kg/ha) in the nine villages and two research stations (Breda and Tel Hadya) and planting dates.

Location (code)	Nitrogen			P ₂ O ₅	Planting date (1996)
	at planting	in Spring	Total		
Ibbin (01)	100	65	165	40	30.12
Ebla (02)	33	25	58	46	8.11
Tel Brak (03)	25	0	25	50	5.11
Jum El-Aswad (04)	46	0	46	23	4.11
Baylonan (05)	10	0	10	10	4.11
Al Bab (06)	23	0	23	23	3.11
Melabya (07)	0	0	0	0	5.11
Bari Sharki (08)	46	0	46	46	7.11
Sauran (09)	46	0	46	40	7.11
Breda (10)	0	0	0	0	14.11
Tel Hadya (11)	40	0	40	50	27.11

Plot size was 8 rows at 20 cm distance and 7.5 m long (12 m²). The total area of the trial was a quarter of a hectare. The agronomic management of the trial was entirely left to each farmer to decide. The application of fertilizer and the planting date in each of the farmers' fields and in the two research stations are given in Table 7. In all the sites the material was evaluated under rainfed conditions.

The plots were laid down in four strips of 52 plots each (Fig. 1); the layout was the same in all farmers' fields and research stations except in one case (Sauran) where the plots were arranged in eight strips of 26 plots each: each plot was identified by a number on a plastic label held by a wooden peg.

The set planted in Bouider was not used partly for logistic reasons and partly because it was an unusually wet season in that site.

Each farmer was given a field book where he recorded the rainfall (measured through a rain gauge) and their selections.

The following activities were performed during 1997:

- a) Individual selection by each participating (host) farmer on his own field: this was repeated a variable number of times during the season and on different traits, and was done without the presence of scientists. Each farmer did his final selection based on visual inspection of the seed characteristics of those entries which received the best score during the last selection before harvesting.
- b) Individual selection by each participating farmer in Breda and Tel Hadya, two research stations representing a stress and a favorable environment, respectively. Each farmer was assisted by a researcher to record both quantitative and qualitative data.
- c) Individual selection by the senior barley breeder of DASR (Directorate of Agricultural and Scientific Research) of the Ministry of Agriculture and Agrarian Reform in Syria in each of the nine farmers' fields as well as in Breda and Tel Hadya. The final selection was based on visual inspection of seed characteristics of those entries which received the best score during the last selection before harvesting.
- d) Group selection by neighbors farmers in five of the nine villages, namely Jum El-Aswad, Baylonan, Al Bab, Bari Sharki and Sauran. In each of the five villages a group of nine farmers did a one-time visual selection with a score from 0 (discarded) to 4 (best) with the assistance of a researcher who helped in recording both quantitative and qualitative data. At the end of the selection process, each farmer was asked to identify the best 15 entries and to rank them from best to worse.
- e) the following characters were recorded by the scientists in each farmer field on a sample of 2.4 m² from each plot:
 - C grain yield
 - C total biological yield
 - C harvest index
 - C plant height
 - C spike length (on a sample of 10 spikes)
 - C number of kernels per spike (on a sample of 10 spikes)
 - C kernel weight
 - C straw characteristics
 - C number of tillers per m² and days from emergence to heading were recorded only at Tel Hadya and Breda.

The physical characteristics of the straw were analyzed with and the following characteristics were measured:

- a. The slope of BEND graph between 0.6mm and 1.0mm displacement, for Lowest Whole Internodes (BENDSLL in g/mm)
- b. The slope of BEND graph between 0.6mm and 1.0mm displacement, for Peduncles (BENDSLP in g/mm)
- c. Shearing energy / DIAM² (CRDIAM² in g.mm/mm²)
- d. Number of force peaks > 1.0 Newton in CRUSH test (CRSHPKS in number)
- e. Shearing energy = Integral of force by distance for CRUSH test (CRUSH in g.mm)
- f. Outside stem diameter measured by CRUSH test (DIAM in mm)

Because of better discriminating power between genotypes we have used DIAM, CRUSH and CRSHPKS as indicators of straw size and strength.

- e) preparation and planting of second year trials

2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1781	1777	1717	1761	1775	1717	1741	1773	1717	1721	1771	1717	1701	1769	1716	1781	1767	1716	1761	1765	1716	1741	1763	1716	1721	1761	1716	1701	1759	1715	1781
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4.2 Results

As expected, there were large differences in average grain yield, biological yield, harvest index and plant height between the nine farmers' fields, Breda and Tel Hadya (Table 8).

Table 8. Rainfall (recorded by farmers through rain-gauges), average grain yield (kg/ha), total biological yield (kg/ha), harvest index and plant height (cm) in the nine farmers' fields and in the two research stations (Breda and Tel Hadya).

Location (code)		Rainfall	Grain Yield	Biol. Yield	Harvest Index	Plant Height ^a
Ibbin (01)	Mean	436.2	3248	8600	0.37	102.1
	s.e.		81	147	0.005	0.57
Ebla (02)	Mean	459.5	2857	8000	0.36	98.0
	s.e.		58	113	0.005	0.65
Tel Brak (03)	Mean	278.4	3685	7661	0.48	87.6
	s.e.		69	101	0.006	0.85
Jum El-Aswad (04)	Mean	284.0	1415	7259	0.20	45.1
	s.e.		51	228	0.005	0.69
Baylonan (05)	Mean	192.9	280	2599	0.11	46.0
	s.e.		13	60	0.004	0.68
Al Bab (06)	Mean	350.0	376	1514	0.24	33.0
	s.e.		15	39	0.009	0.53
Melabya (07)	Mean	241.1	713	2733	0.26	-
	s.e.		29	103	0.005	-
Bari Sharki (08)	Mean	247.5	1017	4534	0.22	52.1
	s.e.		36	163	0.006	0.70
Sauran (09)	Mean	303.2	2515	7117	0.36	69.3
	s.e.		46	101	0.006	0.88
Breda (10)	Mean	233.2	811	2689	0.31	43.7
	s.e.		18	51	0.005	0.59
Tel Hadya (11)	Mean	433.7	4495	12336	0.36	95.6
	s.e.		63	110	0.003	0.72

^a Melabya was not sampled

This was partly due to the different levels of inputs (see Table 7) and partly to the large differences in total rainfall which ranged from less than 200 mm in Baylonan to more than 400 mm in Tel Hadya, Ebla and Ibbin. The coefficients of correlation between total rainfall and grain yield, total biological yield, harvest index and plant height were 0.69, 0.69, 0.52 and 0.73, respectively, and all highly significant ($P < 0.01$), indicating that slightly less than 50% ($R^2 = 0.48$) of the variation in grain yield and total biological yield was associated with the variation in total rainfall. There was a close association between plant height and grain yield ($r = 0.92$).

The highest yield was obtained in Tel Hadya with nearly 4.5 t/ha of grain and over 12 t/ha of total biological yield followed by the locations in the higher rainfall area (zone B) such as Tel Brak

Ibbin, Ebla and Sauran. The two most stressed sites were Baylonan and Al Bab, both in the drier areas (zone C), with less than 0.5 t/ha of grain, a very short crop with a very low harvest index. The fact that Al Bab ranked fourth in rainfall and only 10th in grain yield indicates that the abiotic stresses in this area are much more complex than water availability only.

Table 9. Grain yield (kg/ha) of different barley types^a within the population of 208 entries tested in nine villages and two research stations (Breda and Tel Hadya).

Location	Germplasm type		Row type		Seed color		
	Improved	Landraces	Six-row	Two-row	Black	B/W ^c	White
Ibbin	4129	2444	4108	2970	2228	2157	3554
Ebla	3170	2629	3225	2740	2614	1897	3013
Tel Brak	3713	3729	4065	3563	3463	3087	3794
Jum El-Aswad	1162	1653	1206	1480	1690	1228	1389
Baylonan	275	297	318	269	362	322	261
Al Bab	284	478	254	414	509	416	348
Melabya	577	852	624	742	739	796	699
Bari Sharki	1036	1014	954	1040	943	960	1036
Sauran	2624	2507	2428	2544	2739	2317	2499
Breda	804	849	832	805	924	882	783
Tel Hadya	5046	4043	5026	4330	3808	3811	4695

^a The comparisons are based on 100 improved and 108 landraces, 50 six-row and 158 two-row, and 28 black, 19 segregating black and white and 161 white.

^b Segregating for seed color.

In the highest yielding sites (Tel Hadya, Ibbin, Ebla, Tel Brak and Sauran) improved barleys yielded more grain than landraces except in Tel Brak where the two types of germplasm yielded similarly (Table 9). In the lowest yielding sites, except Bari Sharki, the landraces always yielded more with a yield advantage over the improved ranging from as little as 5% (Breda) to as much as 68% (Al Bab). Six-row types, which were all improved, yielded more than two-rows (1/3 of which were improved and 2/3 landraces) in the highest yielding sites with the exception of Sauran where the yields were similar. In most of the low-yielding sites the two-rows yielded more than six-rows, the exceptions being Breda and Baylonan. Black seeded barleys (all landraces) yielded more than the white seeded types in all but one (Bari Sharki) of the low-yielding sites and also in Sauran. In all other high-yielding sites the white seeded barleys were the highest yielders while the barleys segregating for seed color were intermediate in yield.

The farmers took a variable number of notes during the cropping season (Table 10) using both quantitative and qualitative types of scores. Although the quantitative scoring method suggested by

the breeder was from 1 to 5 (with 1 being the poorest and 5 the best), most of the farmers preferred a 1-4 (or 1-3) scale, one choose a 1-10 scale and eventually one used the 1-4 but with a reverse meaning (1=best, 4= worse).

Table 10. Plant characters and scoring method^a used by the participating farmers on 208 barley populations.

Character	Location code ^b								
	01	02	03	04	05	06	07	08	09
Germ.	-	-	A/B/C	-	-	-	-	-	-
Leaf	-	W/M/N	-	-	-	-	-	-	-
Vigor	-	-	A/B/C	-	-	-	G/M/W	-	-
Frost	+/-	+/-	-	-	-	-	R/M/S	-	-
Till	-	NR.	-	1-10	-	-	-	-	-
Heading	Date	Date	-	1-10	-	-	-	-	-
Stem	-	E/M/P	-	-	-	-	-	-	-
Plant height	-	qual.	-	1-10	-	-	-	-	-
Spike	-	G/M/S	-	-	-	-	G/M/S	-	-
Diseases	P/A	0-3	-	-	-	-	-	-	-
Agr.Sc.	1-3	1-3	A/B/C	1-10	qual	1-4	1-4	1-4	1-4
Seed Sc.	1-3	1-3	A/B/C	1-4	1-3	1-4	1-3	1-4	1-4

^a P/A = present/absent; WM/N = wide/medium/narrow; E/M/P/ = erect/medium/prostrate; G/M/S =good/medium/small; R/M/S/ = resistant/medium/susceptible; qual. = qualitative notes in the numeric score the lowest score indicates undesirability and the highest indicates desirability, with the exception of Al Bab (code 06) where it is the reverse.

^b See Table 7.

The breeder selected visually using an agronomic score from 1 to 5 (with 1 being the poorest and 5 the best) when most of the plots were near physiological maturity. All the nine sites and the two research stations were covered in 10 days. After harvesting, the breeder made a final selection, site by site, based on the seed characteristics (mostly size and plumpness) of the entries which received the best agronomic score as described above. Eventually he prepared a list of selected entries for each site as well as for the two research stations. This took into account not only the evaluation of a line at that site (or station) but also the performance of that line at all sites within the same rainfall area.

Selection of groups of lines: comparison between breeder and farmers

The number of lines selected by the breeder and the farmers in the nine farmers' fields is shown in Table 11 where the total number of selections is divided according to the type of germplasm,

(improved or landraces), the row type (six- or two-row) and the seed color (black, white or segregating).

The data of Table 11 were analyzed in three ANOVAs with Locations and Farmers vs Breeders as constant sources of variation, and with the type of breeding material selected (improved vs. landraces, two-row vs. six-row, and black seeded vs. white seeded) as third source of variation (Table 12).

Table 11. Breeder's and Farmers' selections in each of the nine locations (from the highest to the lowest yielding) classified according to germplasm type (Imp = improved or Land = landraces), row type (6R = six-row vs. 2R = two-row) or seed color (W = white; S = segregating; B = black).

Location	Grain Yield	Selection done by	Total ^a	Imp	Land	6R	2R	W	S	B
Ibbin	3248	Farmer	11	11	0	8	3	11	0	0
		Breeder	73 (5)	53	20	14	59	63	0	10
Ebla	2857	Farmer	11	9	2	6	5	10	0	1
		Breeder	64 (4)	40	24	7	57	51	2	11
Tel Brak	3685	Farmer	13	3	10	0	13	6	1	6
		Breeder	74 (13)	34	40	7	67	59	2	11
Jum El-Aswad	1415	Farmer	9	0	9	0	9	8	0	1
		Breeder	71 (6)	28	43	6	65	54	3	14
Baylonan	280	Farmer	6	0	6	0	6	0	1	5
		Breeder	82 (5)	29	53	8	74	54	12	16
Al Bab	376	Farmer	11	0	11	0	11	7	2	2
		Breeder	71 (8)	22	49	1	70	49	12	10
Melabya	713	Farmer	10	3	7	1	9	7	1	2
		Breeder	66 (2)	24	42	3	63	46	6	14
Bari Sharki	1017	Farmer	14	3	11	0	14	12	1	1
		Breeder	91 (12)	37	54	6	85	71	9	11
Sauran	2515	Farmer	10	5	5	0	10	9	1	0
		Breeder	105 (9)	51	54	10	95	77	14	14

^a In parenthesis the number of lines selected by the breeder which were in common with those selected by the farmer in the same location.

The breeder selected significantly more lines than the farmers in all locations (Table 11 and Table 12), although both made their final selection through a visual inspection of the grain of those lines which had been given the best score during the last visual selection before harvesting. However, the breeder had access to his own selection records from each of the nine fields and used the performance of a line across farmers fields as the final selection criterion. Farmers based their

selection solely on the performance of the lines in their own field and did not use the information on the performance of the lines in Breda and Tel Hadya although this would have been available to them. Although the number of lines selected by the farmer was small (from 6 to 14), only in one case were all the farmer's selections present among the breeder's selections; the largest difference was observed in Melabya where out of the 66 breeder's selections only 2 were in common with the 10 farmer's selections. The maximum similarity was observed in Tel Brak, where all the 13 farmer's selections were included among the 74 breeder's selections, and in Sauran, Bari Sharki and Baylunan.

Both the farmers and the breeder selected significantly more two-row types and more white-seeded types than six-row and black seeded types, respectively, while the total number of improved lines and of landraces selected by the breeder and the farmers was similar. The interaction between who did the selection and the type of germplasm was not significant indicating that the proportion of landraces and improved did not change between the breeder's selections and the farmer's selections. However, there was a significant interaction between the type of germplasm and the locations (LxG) indicating that in some locations (for example Tel Brak, Jum El-Aswad, Bai Sharki, Melabya, Al Bab and Baylunan) both the breeder and the farmer selected more landraces than improved while in others (Ibbin and Ebla) it was the reverse. There was a significant interaction between who did the selection and both the frequency of the row types and the frequency of seed color. The six-row types were 19% of the farmer's selections but only 10% of the breeder's selections, while in the case of the seed color the proportion of black seeded types was a slightly higher among the farmer's selections than among the breeder selections, even though the white-seeded types were the most frequently selected by both breeder and farmers.

Table 12. Analysis of variance of the selection data of Table 11.

Sources of variation	Imp. vs. Land.			Six-vs. Two-row		Seed Color		
	d.f.	Mean	F	Mean	F	d.f.	Mean	F
Farmer vs Breeder (FB)	1	10068.8	240.5**	10068.8	503.3**	1	6711.2	455.9**
Germplasm (G)	1	215.1	1.2	11306.8	142.4**	2	4584.2	139.1**
FB x G	1	32.1	0.8	7168.4	350.6**	2	2692.1	182.9**
Locations (L)	8	45.3	0.2	45.3	0.6	8	30.2	0.9
L x FB	8	44.3	1.1	44.3	2.2	8	29.5	2.0
L x G	8	181.6	4.3*	81.5	4.0*	16	32.9	2.2
L x G x FB	8	41.9		20.4		16	14.7	

Although the two-row types were selected more frequently than six-row types, the difference between the selected entries of the two different row types changed with the location, as indicated by a significant L x G interaction.

Selection of groups of lines: Decentralization and Participation

A comparison of interest to obtain information on the role of the selection environment, i.e. of decentralized selection, and of farmers' participation is reported in Table 13 where we show the total number of barley entries selected by each farmer in his own field and in the two research stations (Breda and Tel Hadya) and by the breeder in the two research stations (Breda and Tel Hadya), as well as the percent of improved and landraces and of two-row and six-row selected by the farmers and the breeder in each environment.

Table 7. Selection by individual farmers (identified by the location name) in their own field, in Tel Hadya and Breda, selection by the breeder in Tel Hadya and Breda, and G tests for independence^a(1 for Improved vs. Landraces and 2 for six-row vs two-row). The data are percent of the total number of lines selected

Selection done by	Selection done in	Total	% of impr.	% of land.	% of six-row	% of two row	G-test (1)	G-test (2)
Ibbin	own field	11	100.0	0.0	72.7	27.3	0.1	0.1
	Tel Hadya	17	100.0	0.0	70.6	29.4	25.1**	22.4**
	Breda	32	12.5	87.5	0.0	100.0	35.6**	28.2**
Ebla	own field	11	81.8	18.2	54.6	45.4	0.0	8.5**
	Tel Hadya	26	80.8	19.2	7.7	92.3	13.7**	9.4**
	Breda	21	14.3	85.7	4.8	95.2	21.6**	0.1
Tel Brak	own field	13	23.1	76.9	0.0	100.0	8.3**	0.7
	Tel Hadya	61	67.2	32.8	11.5	88.5	2.0	0.1
	Breda	43	7.0	93.0	2.3	97.7	42.0**	3.2
Jum El-Aswad	own field	9	0.0	100.0	0.0	100.0	20.7**	0.1
	Tel Hadya	22	90.9	9.1	0.0	100.0	1.2	0.1
	Breda	23	21.7	78.3	0.0	100.0	23.4**	0.1
Baylonan	own field	6	0.0	100.0	0.0	100.0	9.1**	0.1
	Tel Hadya	12	83.3	16.7	0.0	100.0	1.4	0.3
	Breda	46	30.4	69.6	2.2	97.8	10.8**	0.1
Al Bab	own field	11	0.0	100.0	0.0	100.0	15.2**	2.4
	Tel Hadya	97	61.9	38.1	22.7	77.3	1.8	0.1
	Breda	44	20.5	79.5	2.3	97.7	21.5**	11.6**
Melabya	own field	10	30.0	70.0	10.0	90.0	4.3*	1.0
	Tel Hadya	59	66.1	33.9	23.7	76.3	0.5	0.1
	Breda	57	42.1	57.9	12.3	87.7	6.7**	2.5
Bari Sharki	own field	14	21.4	78.6	0.0	100.0	6.4*	0.2

	Tel Hadya	27	70.8	29.2	7.4	92.6	1.9	0.6
	Breda	28	42.9	57.1	10.7	89.3	2.2	0.2
Sauran	own field	10	50.0	50.0	0.0	100.0	7.8**	6.2*
	Tel Hadya	31	93.6	6.4	45.2	54.8	0.6	0.1
	Breda	20	35.0	65.0	0.0	100.0	20.1**	12.9**
Breeder	Tel Hadya	70	74.3	25.7	20.0	80.0	14.9**	13.6**
	Breda	67	41.8	58.2	1.5	98.5		

^a For each farmer the first line shows the G-test for the comparison farmer field vs. Tel Hadya, the second shows the G-test for the comparison farmer field vs. Breda and the third the G-test for the comparison Breda vs. Tel Hadya. For the breeder there is only the comparison between Breda and Tel Hadya.

Selection done by the farmers in their own fields is a case of decentralized and participatory selection, the selection done by the farmers in the research stations is a case of centralized and participatory selection, while the selection done by the breeder in the research station is a typical centralized non-participatory selection. Later we will also show the data of decentralized-non participatory selection, i.e. the selection done by the breeder in the farmers' fields.

Entries were considered selected when they were among those receiving the two highest scores: this was necessary because some farmers gave every line a score. The observed numbers of selections of different types were compared with the numbers expected in case of independent events with a G-test for contingency tables. The farmers from two high yielding sites (Ibbin and Ebla) selected more improved types than landraces both in their fields and at Tel Hadya; in these two locations also the breeder selected more improved than landraces (Table 5). These were also the only two cases where farmer selection in their fields and Tel Hadya did not differ. All the other farmers selected more landraces than improved in their field (three farmers selected only landraces in their fields) and more improved than landraces at Tel Hadya. As a result, there was a high degree of dissimilarity in the frequency with which improved and landraces were selected by the farmers in their fields and in Tel Hadya.

By contrast, there was a high degree of similarity in the frequency with which improved and landraces were selected by the farmers in their fields and in Breda: the only significant differences were observed again in the case of the two farmers from Ibbin and Ebla. The farmer in Sauran selected the same number of landraces and improved in his field but, like the other farmers, more improved than landraces in Tel Hadya.

As expected from the previous results, there was also a high degree of dissimilarity between the selections done by the farmers (as well as by the breeder) in Breda and Tel Hadya. With the only

exception of the farmer from Bari Sharki, both the farmers and the breeder selected more landraces in Breda and more improved in Tel Hadya.

The data of Table 7 suggest that when the germplasm is classified into broad categories such as landraces and improved, the selection seems to be environmentally driven, i.e. the role of the selection environment is more important than the role of who does the selection. In other words decentralization seems to play a more important role than participation.

The selections done by the farmers and the breeder were also compared in relation to the frequency of two-row and six-row types (last column of Table 7) and of black- and white-seeded types (Table 8).

Table 8. Selection by individual farmers (identified by the location name) in their own field, in Tel Hadya and Breda, selection by the breeder in Tel Hadya and Breda classified by seed color, and G tests for independence^a. The data are percent of the total number of lines selected.

Selection done by	Selection done in	Total	% of			G-test
			white	segregating	black	
Ibbin	own field	11	100.0	0.0	0.0	0.1
	Tel Hadya	17	100.0	0.0	0.0	5.2*
	Breda	32	56.3	21.9	21.8	8.3**
Ebla	own field	11	90.9	0.0	9.1	0.3
	Tel Hadya	26	84.6	0.0	15.4	2.8
	Breda	21	66.7	14.3	19.0	1.5
Tel Brak	own field	13	46.2	7.6	46.2	10.0**
	Tel Hadya	61	83.6	9.8	6.6	0.3
	Breda	43	53.5	9.3	37.2	15.2**
Jum El-Aswad	own field	9	88.9	0.0	11.1	0.2
	Tel Hadya	22	90.9	0.0	9.1	2.9
	Breda	23	52.2	8.7	39.1	6.9**
Baylonan	own field	6	0.0	16.6	83.4	12.2**
	Tel Hadya	12	100.0	0.0	0.0	8.3**
	Breda	46	67.4	10.9	21.7	3.5
Al Bab	own field	11	63.6	18.2	18.2	2.2
	Tel Hadya	97	84.5	9.3	6.2	0.0
	Breda	44	63.6	18.2	18.2	2.2
Melabya	own field	10	70.0	10.0	20.0	1.8
	Tel Hadya	59	84.7	10.2	5.1	0.1
	Breda	57	75.4	7.0	17.6	4.7*
Bari Sharki	own field	14	85.7	7.1	7.2	0.4
	Tel Hadya	27	77.8	11.1	11.1	2.3
	Breda	28	64.3	17.9	17.8	1.2
Sauran	own field	10	90.0	10.0	0.0	0.9
	Tel Hadya	31	96.8	0.0	3.2	2.0
	Breda	20	70.0	5.0	25.0	6.7*

Breeder	Tel Hadya	70	88.6	0.0	11.4	8.8**
	Breda	67	71.6	10.4	18.0	

^a For each farmer the first line shows the G-test for the comparison farmer field vs. Tel Hadya, the second shows the G-test for the comparison farmer field vs. Breda and the third the G-test for the comparison Breda vs. Tel Hadya. For the breeder there is only the comparison between Breda and Tel Hadya.

While the two farmers from Ibbin and Ebla (two of the high yielding sites) selected more six-row types than two-row types in their field, all the others virtually ignored six-rows in their fields but the majority (the exception are the two farmers from Baylonan and Jum El-Aswad) selected some, and in three cases several, six-row types in Tel Hadya. Therefore, in four cases there was no significant difference between the frequency with which two-rows and six-rows were selected by farmers in their fields and at Tel Hadya. In Breda the attitude of farmers towards six-rows was similar to what was observed in farmers' fields even in those farmers who selected a relatively large number of six-rows in their fields.

In the case of seed color, and even more so in the case of row type there was more similarity in the selection done by farmers and breeders in the different locations than in the case of improved vs. landraces. This suggests that for these two traits the selection is driven more by who does the selection than by the environment, although the latter also affects the selection indirectly because the three traits are not fully independent.

As mentioned earlier, white seeded types were selected more frequently than black-seeded types by every farmer and everywhere, with only two exceptions: the farmer from Baylonan, who did not select any white-seeded in his own field, and the farmer from Tel Brak, who selected in his own field an equal proportion of black and white. The selection done by some farmers in relation to seed color was consistent across locations (Ebla, Al Bab, Bari Sharki). Other farmers changed their preferences moving from their field to Tel Hadya and Breda. A typical example of this is the farmer of Baylonan who selected only black-seeded and segregating types in his field and only white-seeded types in Tel Hadya. Both the farmer and the breeder selected more black-seeded types in Breda than at Tel Hadya. This to some extent reflects the different adaptation to different environments of black- and white-seeded types (all improved are white-seeded and all the black-seeded are landraces).

The comparison involving seed color is biased by the fact that farmers did not have the same opportunities to select for this trait at all locations. In fact, they did the final selection in their field by inspecting the seed after harvesting, selected the crop in Breda when the seed color was already

developed, and selected in Tel Hadya when a number of entries were in the early grain filling stages and the seed color could not be observed.

Selection of individual lines

In the previous sections, we have discussed similarity (or dissimilarity) of selection at the level of groups of lines classified on the basis of the type of germplasm, the seed color or the row type. In this section we will analyze the similarity of selection at the level of individual lines.

The similarity of selection done in different environments by the breeder and by the individual farmer as well as by the groups of farmers, was evaluated with different methods, from the simple visual comparison of lines selected in the different environments by the breeder and the farmers to the calculation of simple correlation coefficients, to the calculation of percent of lines selected in common (in different environments or by different selectors), to the use of the similarity analysis based on the Dice coefficient (Dice, 1945). After reducing the selection data into a matrix of 1 (selected) and 0 (discarded), the Dice coefficient is calculated as $\frac{2a}{2a+b+c}$ where a (1/1) is a case when a line is selected twice (for example by both the breeder and a farmer, or in two environments), b (1/0) and c (0/1) are the two possible cases when a line is selected only once out of two possibilities, and d (0/0) is a case when a line is discarded twice. The Dice coefficient (as indicated by the formula) does not consider the number of discards, and therefore is an index of similarity in positive selection only. The dendograms of the various combinations of environments of selection and selectors were obtained by the unweighted pair group method with arithmetic average (UPGMA) cluster analysis. These analysis were done using the program NTSYS-PC version 1.80 (Numerical Taxonomy System, Applied Biostatistics, N.Y.). The different methods gave results in close agreement with each other and therefore, with few exceptions, we present the data obtained with the similarity analysis.

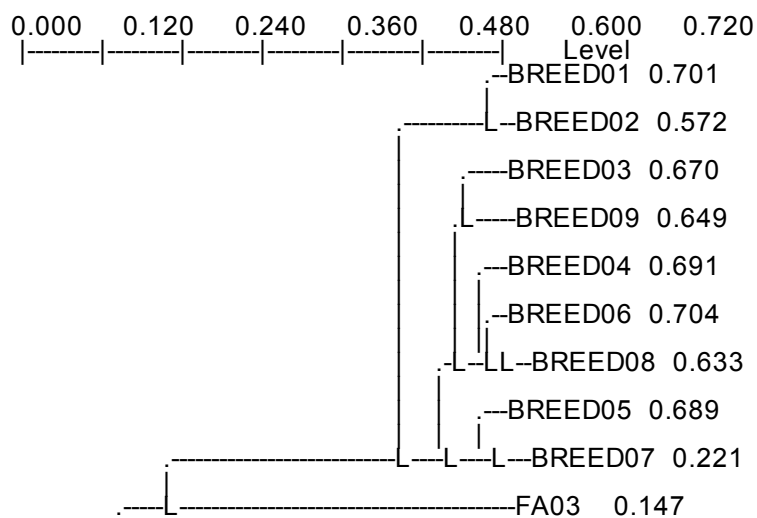
We will analyze in particular the following comparisons:

1. Selection by farmers and breeder in the farmer fields: this provides a comparison between decentralized-participatory selection and decentralized-non participatory selection;
2. Selection by farmers in their fields and by the breeder in the research stations: this provides a comparison between decentralized-participatory selection and centralized-non participatory selection;
3. Selection by the breeder in the research stations and in the farmers fields: this provides a comparison between centralized-non participatory selection and decentralized-non participatory selection;

4. Selection by the farmers in the research stations and in their fields: this provides a comparison between centralized-participatory selection and decentralized-participatory selection
5. Selection by the breeder and the farmers in the research stations: this provides a comparison between centralized-non participatory selection and centralized-participatory selection;
6. Selection by the breeder in the farmers' fields and by the farmers in the research stations this provides a comparison between centralized-participatory selection and decentralized-non participatory selection;

1. *Selection by farmers and breeder in the farmer fields*

Fig. 2 shows the dendrogram of the nine host farmers and of the breeder based on cluster analysis of their selections in the nine farmers fields. There was a high degree of similarity among the selections done by the breeder in the various farmer fields and a much lower degree of similarity among the selections done by the farmers in their fields. Also there was little similarity between the selections done by the breeder and the farmer in the same field. This is certainly the reflection of how selection was done, as mentioned earlier, and of the large difference in the number of entries selected by the breeder and by the farmers (Table 5). The large dissimilarity between the lines selected by the farmers in different locations should result in a higher diversity left in the breeding material after one cycle of selection by the farmers than after one cycle of selection by the breeder. These data show that at the level of individual line selection, decentralized breeding can give very different results depending on whether is participatory or not. This does not contradict the evidence presented earlier about the environmentally driven selection in the case of landraces and improved: even though there was agreement on which type of germplasm performed better in a given environment, the actual lines which were selected within that type of germplasm were different.



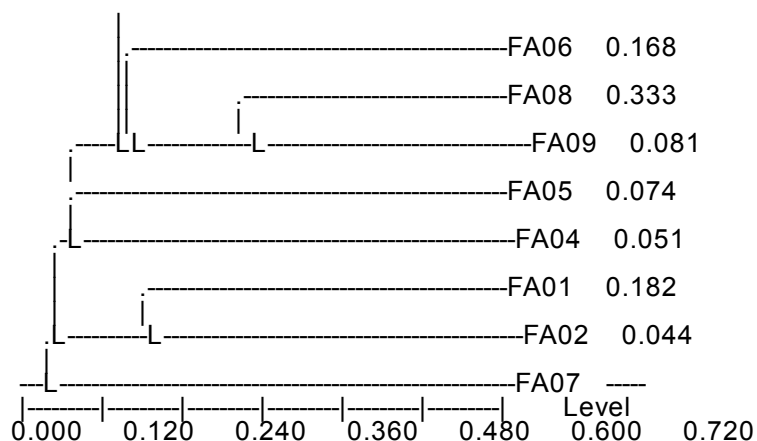


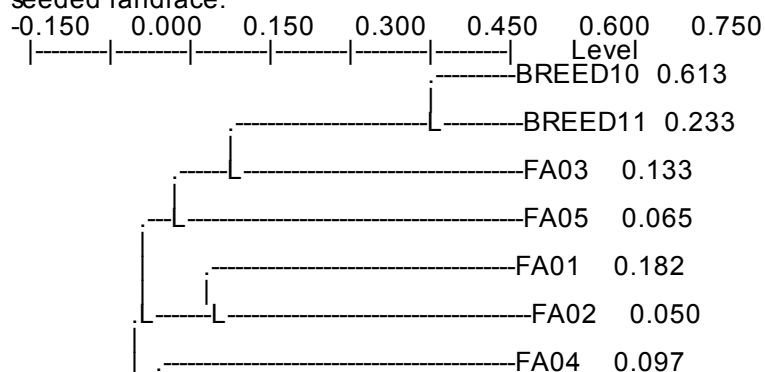
Fig. 2 . Dendrogram of the nine host farmers and of the breeder based on cluster analysis of their selections in farmers' fields (FA= farmer, BREED= breeder). Individual locations are indicated with the location code.

2. Selection by farmers in their fields and by the breeder in the research stations.

There was much more similarity between the lines selected by the breeder in Breda and Tel Hadya than between these and the lines selected by the farmers in their fields (Fig. 3). This would suggest either that Tel Hadya and Breda do not represent anyone of the environments sampled with the nine locations, or that the selection criteria used by the breeder are very different from those used by any of the farmers, or a combination of the two. In either case this underlines that centralized-non participatory selection may identify lines which are very different from those identified by decentralized-participatory selection.

3. Selection by the breeder in the research stations and in the farmers fields

There was a large similarity between the selection done by the breeder on station and on farm (Fig 4) with similarity coefficients equal or greater than 0.58. Selections made in Tel Hadya (11) tend to cluster together with the selections at some of the other high yielding locations such as Ibbin (01), Ebla (02) and Sauran (09). Selections made in Breda (10), by contrast, tend to cluster together with most of the low yielding locations. Among these is included Tel Brak (03) which, as mentioned earlier, is the only high yielding location where the black seeded landrace is preferred to the white seeded landrace.



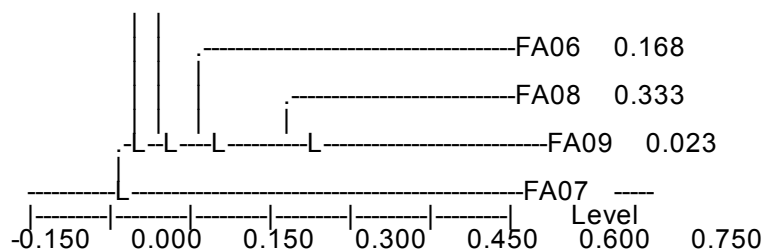


Fig. 3. Dendrogram of the nine host farmers and of the breeder based on cluster analysis of the breeder selection in Tel Hadya and Breda and of the farmers' selections in their own fields (FA= farmer, BREED= breeder). Individual locations are indicated with the location code.

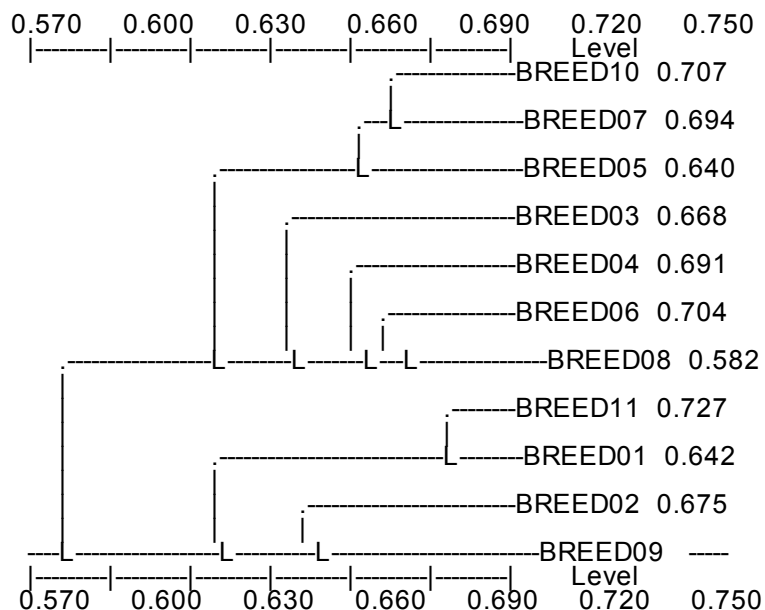
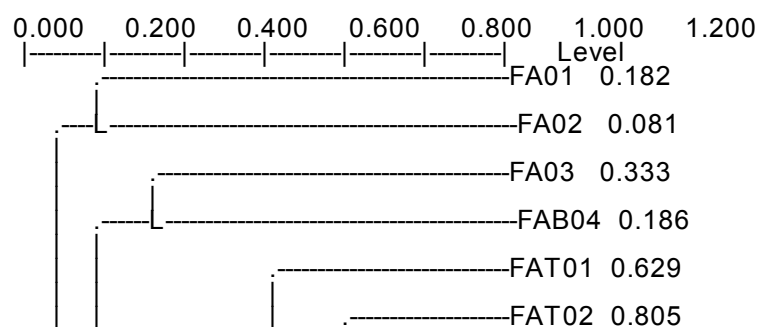


Fig. 4. Dendrogram based on cluster analysis of breeder's selections in farmers' fields, in Tel Hadya and Breda (BREED= breeder). Individual locations are indicated with the location code.

4. Selection by the farmers in the research stations and in their fields.

When we compared farmers' selections in Tel Hadya, in Breda and in their own fields (Fig. 5), the similarity among the selections done in Breda was higher than in Tel Hadya, while, as already shown in Figures 2 and 3, there is no similarity among the selections done in farmers' fields. In Breda, with the exception of the farmer from Jum El-Aswad (code 04), most of the farmers' selections tend to cluster together.



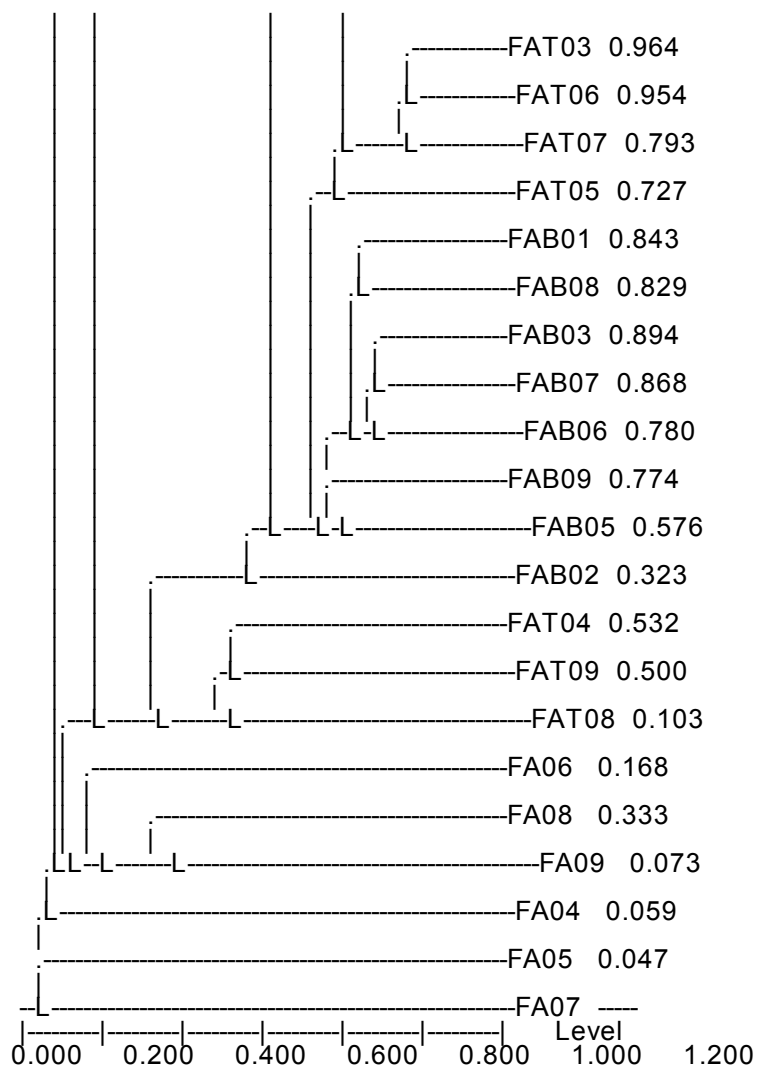


Fig. 5. Dendrogram of the nine host farmers based on cluster analysis of their selections in Breda (FAB), in Tel Hadya (FAT) and in their own field (FA). Individual farmers are indicated with the location code.

In Tel Hadya, there was similarity between the selections done by six of the nine farmers (01, 02, 03, 05, 06, and 07) while farmers 04, 08 and 09 seem to be less similar among themselves and with the others.

As indicated earlier, the lowest degree of similarity is found in the selection done by the farmers in their own fields. The dice coefficients were always very low (the highest is 0.333) and it is not possible to identify a single cluster, either between different farmers fields, or between farmers fields and either Breda or Tel Hadya.

The low similarity between the lines selected by the individual farmers in their fields is confirmed by the data of Table 9. In total 75 lines (36% of the total) were selected by at least one farmer in his field (data not shown), only 18 (8.7%) were selected by at least two farmers, and only

two (0.96%) were selected by three farmers (lines 187 and 131). Only two of the lines most frequently selected by farmers were six-row; these were selected in the two high yielding sites (Ibbin and Ebla) by both farmers but not by the breeder. All the other lines were also selected by the breeder; in some cases there was a perfect similarity such as in the case of lines 199 and 208, which were selected by the breeder in the same locations as the farmers.

Table 9. The barley lines most frequently selected by the individual farmers in their fields (RT= row type, Germ = Germplasm type; Col = seed color), nr. of fields in which they were selected (Tot) and number of times the line was selected by the breeder in the nine farmers □ fields (Breeder).

Nr	RT	Germ ^b	Col ^c	Location ^a									Tot	Breeder
				01	02	03	04	05	06	07	08	09		
187	2	L	1	0	0	0	0	0	1	0	1	1	3	6
131	2	L	1	0	1	0	1	0	0	0	0	1	3	6
105	2	I	1	1	0	1	0	0	0	0	0	0	2	5
118	2	L	1	0	0	0	0	0	0	0	1	1	2	9
111	2	L	1	0	0	0	0	0	1	0	1	0	2	9
93	2	I	1	0	0	0	0	0	0	1	1	0	2	5
41	2	I	1	0	1	1	0	0	0	0	0	0	2	9
104	2	I	1	0	0	0	0	0	0	1	0	1	2	9
95	2	I	1	0	0	0	0	0	0	0	1	1	2	9
199	2	L	1	0	0	0	0	0	1	0	1	0	2	2
204	2	L	1	0	0	0	1	0	0	0	1	0	2	6
208	2	L	1	0	0	0	0	0	0	0	1	1	2	4
183	2	L	1	0	0	0	1	0	1	0	0	0	2	4
142	2	L	3	0	0	1	0	1	0	0	0	0	2	9
181	2	L	3	0	0	1	0	0	1	0	0	0	2	8
182	2	L	3	0	0	1	0	1	0	0	0	0	2	9
12	6	I	1	1	1	0	0	0	0	0	0	0	2	0
3	6	I	1	1	1	0	0	0	0	0	0	0	2	0

^a Location code as in Table 1

^b Germplasm type (L = landraces; I = Improved)

^c Seed color (1 = white; 3 = black)

In other cases the similarity was only partial since the lines were selected by the breeder in some of the locations where they were selected by the farmers and also in some locations were they were discarded by the farmers such as line 93; this was selected by the breeder in locations 1, 2, 4, 8 and by the farmer in locations 7 and 8.

Table 10. Farmer selection in Breda and Tel Hadya: Number and percent of lines selected by decreasing number of farmers.

Number of farmers	Breda		Tel Hadya	
	Number of lines	%	Number of lines	%

all	11	5.3	11	5.3
8	46	22.1	12	5.8
7	36	17.3	25	12.0
6	24	11.5	41	19.7
5	14	6.7	45	21.6
4	23	11.1	30	14.4
3	20	9.6	12	5.8
2	15	7.2	3	1.4
1	8	3.9	13	6.3
0	11	5.3	16	7.7

Table 11. Barley lines selected by all nine farmers in Breda with the row type (RT), seed color (Col), mean score, and the coefficient of variation (C.V.)

Breda						
Entry	Name	RT	Col ^e	Score	CV	
20	Local 1	2	3	3.00	0.33	
156	Moroc 9-75/Arabi Aswad	2	3	2.94	0.32	
40	Local 2	2	3	2.67	0.32	
41	ChiCm/An57//Albert/3/Alger/Ceres.362-1-1	2	1	2.56	0.35	
155	H.spont.41-1/Tadmor	2	1	2.33	0.21	
118	SLB 34-65/Arar	2	1	2.33	0.21	
46	Lignee 1242/3/Arr/Esp//Alger/Ceres,362-1-1	2	1	2.33	0.30	
139	Arar/Arabi Aswad	2	3	2.17	0.52	
131	WI 2291/Tadmor	2	1	1.72	0.53	
38	Cerise/Lignee 1479//Moroc 9-75/PmB	2	1	1.67	0.30	
119	ER/Apm//Lignee 131/3/Lignee 131/Arabi Abiad	2	1	1.39	0.50	

^a 1=white; 3 = black

Table 12. Barley lines selected by all nine farmers in Tel Hadya with the row type (RT), seed color (Col), mean score, and the coefficient of variation (C.V.)

Tel Hadya						
Entry	Name	RT	Col ^a	Score	CV	
95	Moroc 9-75//WI2291/WI2269	2	1	2.89	0.21	
39	WI2269//Alger/Ceres.362-1-1	2	1	2.89	0.40	
27	Harmal	2	1	2.78	0.35	
29	Emir/Sbt//CM67/3/F8-HB-854-23/121//148-221/4/ CI 08887/CI 05761/5/Dram/Emir//ER/Apm	2	1	2.78	0.35	
45	Harmal-02/5/WI2291/4/Avt/Ki//Avt/3/Toll/Bz	2	1	2.67	0.27	
104	Moroc 9-75/4/Roho//Alger/Ceres.362-1-1/3/Kantara	2	1	2.56	0.35	
182	SLB45-58/Arta	2	3	2.33	0.37	

50	WI2291/Roho//WI2269	2	1	2.33	0.43
36	ER/Apm/3/Arr/Esp//Alger/Ceres.362-1-1/4/ER/Apm//WI2198	2	1	2.22	0.38
149	WI 2291/Tadmor	2	3	2.22	0.44
35	CI 08887/CI 05761//Cerise/5/Emir/Sbt//CM67/ 3/F8-HB-854-23/121//148-221/4/CI 08887/CI 05761	2	1	2.11	0.28

^a 1=white; 3 = black

The similarity among the farmers' selections in Breda and Tel Hadya is also illustrated by the data of Tables 10 and 11 where we show the number and frequency of lines selected by a decreasing number of farmers. In both stations eleven lines were selected by all the farmers: however, none of the eleven lines selected by all the farmers in Breda was in common with the eleven lines selected by all the farmers in Tel Hadya (Tables 11 and 12). Nearly all the farmers (eight out of nine) selected 57 lines (27.4 % of the total) in Breda, but only 23 (11.1% of the total) in Tel Hadya. The number of lines selected by seven or more farmers was 93 (44.7% of the total) in Breda, nearly double the number of lines selected by the same number of farmers in Tel Hadya (48 or 23.1%).

The majority (eight) of the eleven lines selected by every farmer in Breda were landraces while the number of white and black seeded types were nearly the same (Table 11). Only three lines (41, 118 and 131) among those selected more frequently by farmers in Breda were also among the lines most frequently selected by farmers in their fields and only one (104) line was also among the lines most frequently selected by farmers in Tel Hadya (compare Table 9 with Tables 10 and 12).

The eleven lines selected by every farmers at Tel Hadya (Table 12) were all two-row, the majority (nine) were improved with white seed and only two were landraces with black seed.

The average scores were more variable in Breda (from 1.39 to 3.00) than in Tel Hadya (from 2.11 to 2.89), indicating that some of the lines, such as line 119, were selected by all farmers but with low and variable (as indicated by the high CV) scores. In other cases, such as line 95 selected in Tel Hadya, there was similarity both in choosing and in scoring the line. This comparison indicates that farmers' selection on station (centralized-participatory selection) leads to more uniform breeding material than farmers' selection in farmers fields (decentralized-participatory selection), and that this is particularly true if the research station simulates a stress environment.

5. Selection by the breeder and the farmers in the research stations

In Figure 6 we compare farmers' selections and breeder selection in Tel Hadya and in Breda. Contrary to what we found when the comparison was made in farmers' fields, and confirming what shown partially in the previous Figures, selections on station tend to be much more similar than selection in farmers' fields. As expected, breeder's selections in Tel Hadya clustered together with

the selections of some of the farmers from high rainfall areas, such as 01, 02 and 03 (but not with 09).

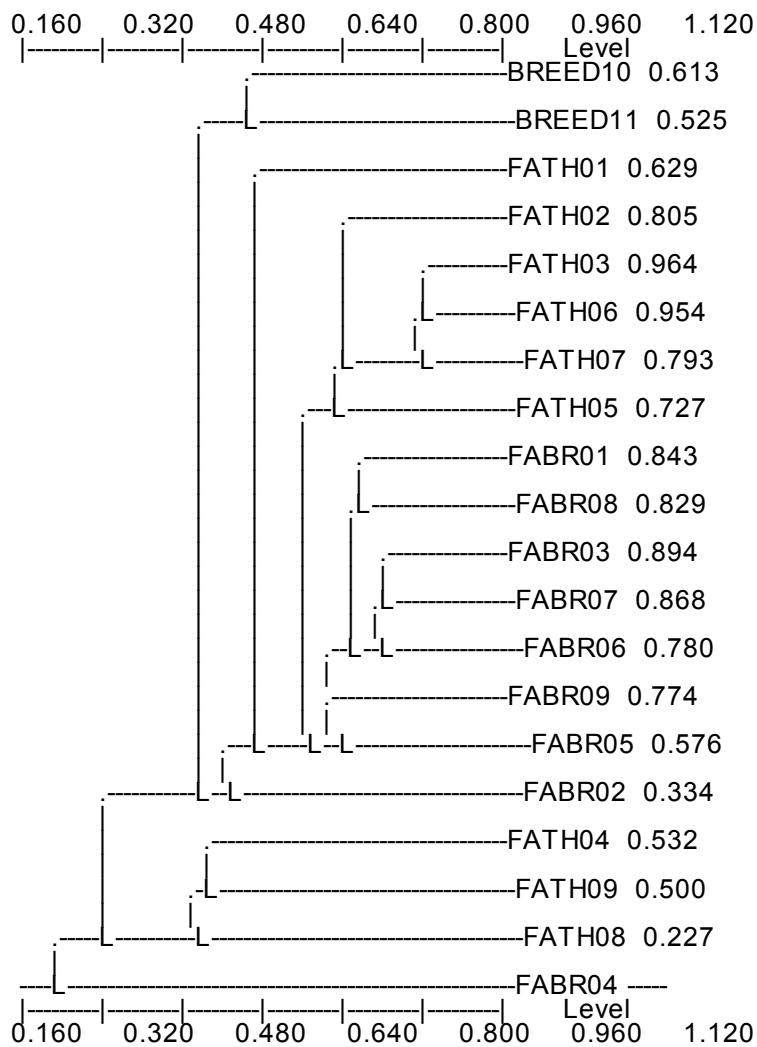
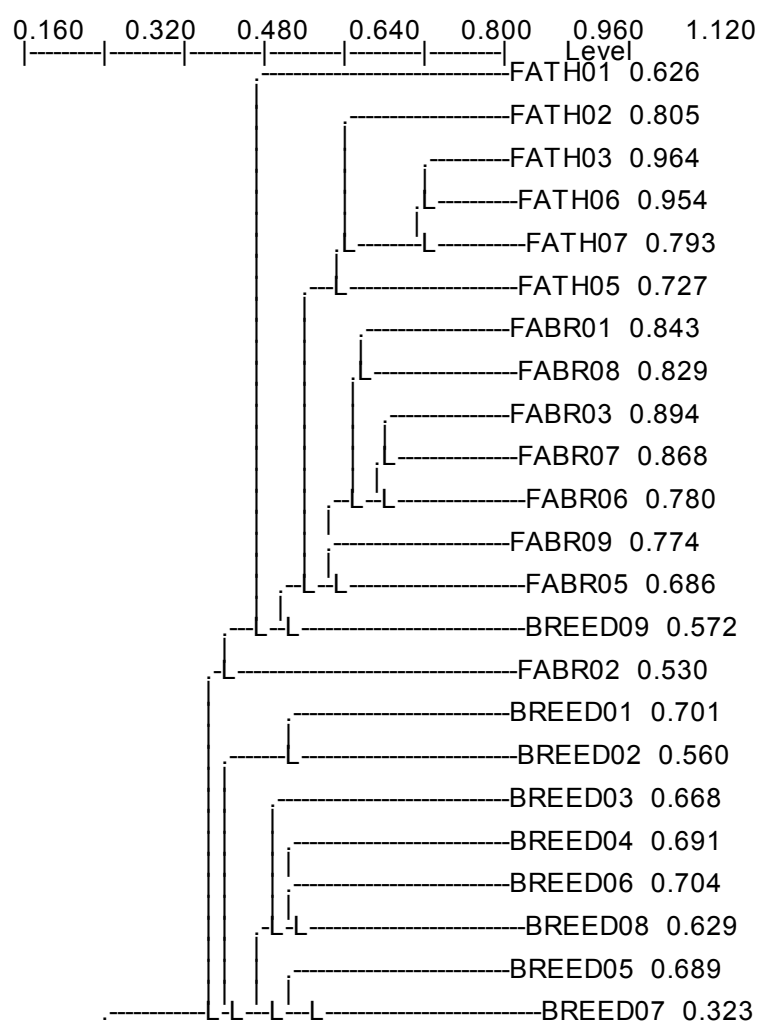


Fig. 6. Dendrogram of the nine host farmers and of the breeder based on cluster analysis of their selections in Tel Hadya and in Breda (FA=farmer; BREED = breeder, TH = Tel Hadya, BR = Breda). Individual farmers are indicated with the location code.

Breeder's selections in Breda and Tel Hadya are more similar than expected. Most of the similarity coefficients relative to breeder and farmers selections are considerably less different than those shown in Fig. 2 (selection by farmers and breeder in the farmer fields) and of the same order of magnitude of the similarity coefficients of breeder's selections in Breda. This shows once again the power of the environment in making the selections more or less similar.

6. Selection by the breeder in the farmers fields and by the farmers in the research stations.

The dendrogram resulting from the diversity coefficients between the selection made by the breeder in the farmers' fields and those made by the farmers in the research stations (Fig. 7) shows two main clusters representing the farmers' selections in Breda which includes all farmers except FABR04, and the breeder's selections in farmers' fields, respectively. The selections of six farmers in Tel Hadya (01, 02, 03, 05, 06, 07) clustered together with most of the farmers' selections in Breda, while the remaining three did not show any particular pattern.



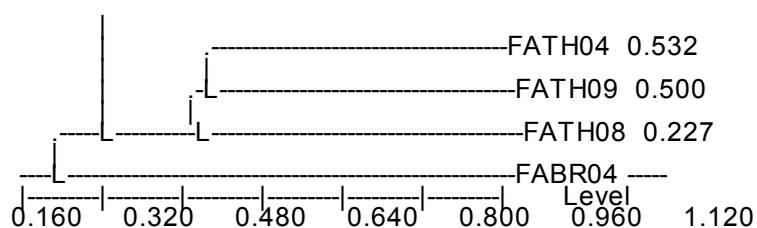


Fig. 7. Dendrogram of the nine host farmers and of the breeder based on cluster analysis of farmers' selections in Tel Hadya and in Breda and of breeder's selections in the farmers' fields (FA=farmer; BREED = breeder, TH = Tel Hadya, BR = Breda). Individual farmers are indicated with the location code.

Group selection

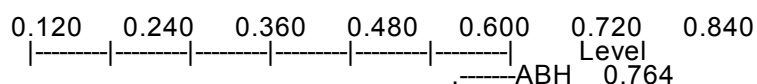
The data shown in the previous section could be biased by (1) the fact that in farmers fields only one farmer made the selection, and (2) by the fact that the selections of one breeder were compared with the selections of nine farmers. The analysis of the data obtained in the five villages where we conducted "group selection" should provide an answer to questions such as "how representative was the selection of the host farmer in each particular farmers field?" and "to what an extent the differences between breeder's and farmers' selections depends on the that particular host farmers?".

The number of lines selected by each individual farmer varied, but with some exceptions was not very different from the number of lines selected by the breeder (Table 13).

Table 13. Number of lines selected by individual farmers during group selection in five locations and number of lines selected by the breeder in the same locations (numbers are arbitrary: there is no relationship between farmers in different locations except that nr. 1 is always the host farmer).

Location (code)	1	2	3	4	5	6	7	8	9	Breed
Jum El-Aswad (04)	54	42	57	58	65	61	31	133	-	71
Baylonan (05)	40	105	71	71	33	96	78	40	-	82
Al Bab (06)	81	13	76	18	20	59	11	8	-	67
Bari Sharki (08)	70	45	36	116	49	38	45	13	42	91
Sauran (09)	57	76	81	80	109	64	117	79	-	105

Figures 8, 9, 10, 11, 12 and 13 shows the dendrograms of the group selection conducted in five locations obtained with the methodology described earlier. In each graph, the host farmer is indicated by an "H" rather than by a number, while the breeder selections (in Breda, in Tel Hadya and in that particular location) are indicated as in the previous Figures.



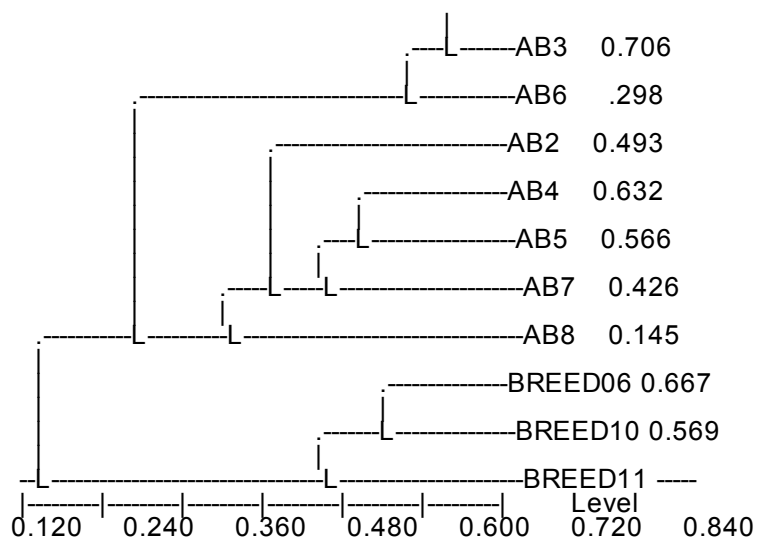


Fig. 8. Dendrogram of the host farmer, of other seven farmers, and of the breeder based on cluster analysis of group selection in Al Bab (AB) and of breeder's selections in Tel Hadya, in Breda and in Al Bab (H= host farmer; BREED = breeder, 11 = Tel Hadya, 10 = Breda, 06 = Al Bab). Individual farmers are indicated with a number.

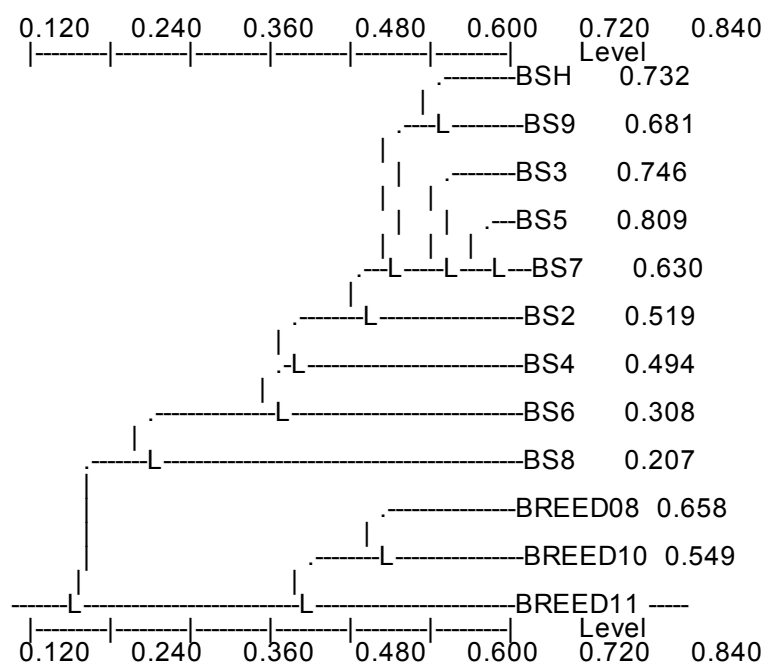
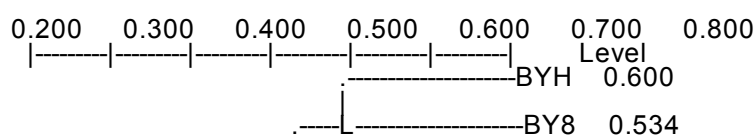


Fig. 9. Dendrogram of the host farmer, of other eight farmers, and of the breeder based on cluster analysis of group selection in Bari Sharki (BS) and of breeder's selections in Tel Hadya, in Breda and in Bari Sharki (H= host farmer; BREED = breeder, 11 = Tel Hadya, 10 = Breda, 08 = Bari Sharki). Individual farmers are indicated with a number.



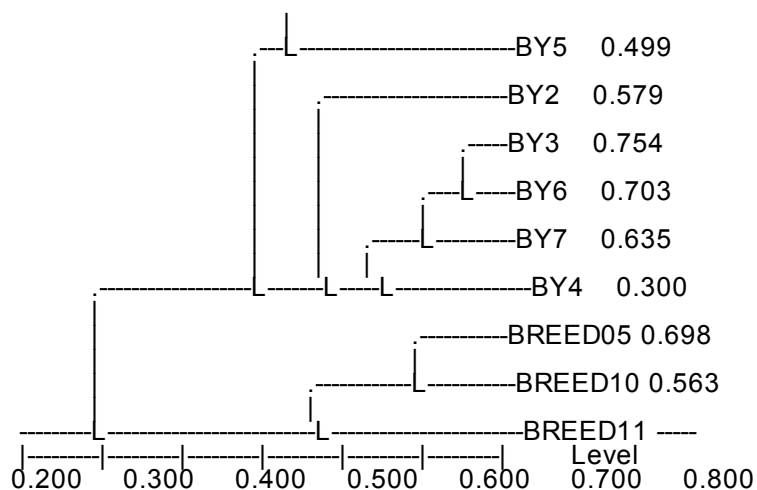


Fig. 10. Dendrogram of the host farmer, of other seven farmers, and of the breeder based on cluster analysis of group selection in Bylonan (BY) and of breeder's selections in Tel Hadya, in Breda and in Bylonan (H= host farmer; BREED = breeder, 11 = Tel Hadya, 10 = Breda, 05 = Bylonan). Individual farmers are indicated with a number.

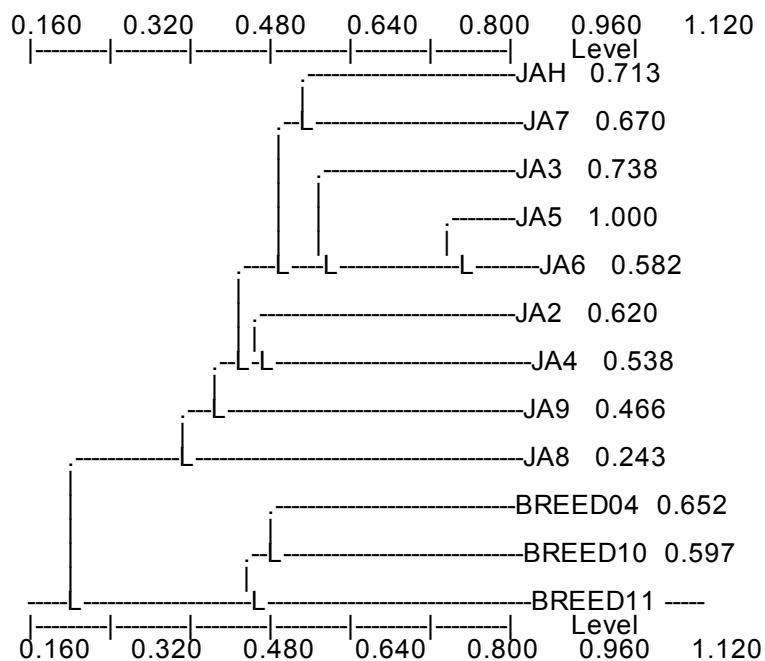


Fig. 11. Dendrogram of the host farmer, of other seven farmers, and of the breeder based on cluster analysis of group selection in Journ El-Aswad (JA) and of breeder's selections in Tel Hadya, in Breda and in Journ El-Aswad (H= host farmer; BREED = breeder, 11 = Tel Hadya, 10 = Breda, 04 = Journ El-Aswad). Individual farmers are indicated with a number.



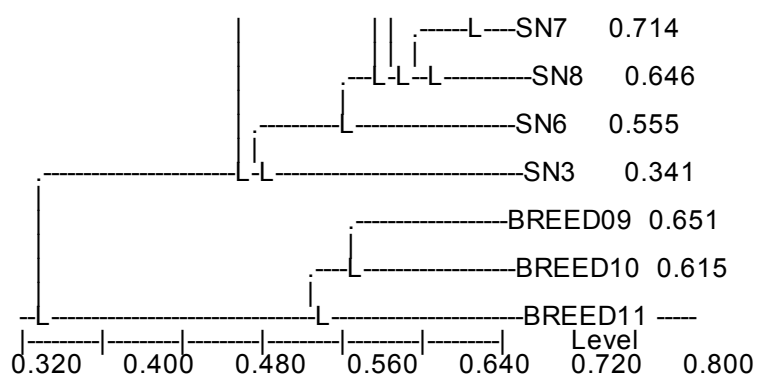


Fig. 12. Dendrogram of the host farmer, of other seven farmers, and of the breeder based on cluster analysis of group selection in Sauran (SN) and of breeder's selections in Tel Hadya, in Breda and in Sauran (H= host farmer; BREED = breeder, 11 = Tel Hadya, 10 = Breda, 09 = Sauran). Individual farmers are indicated with a number.

There are various degrees of similarity among the lines selected by the farmers groups in each location, without any consistent pattern. The only consistent pattern was that in all five locations the selections done by the breeder never clustered together with the farmers selections, regardless of which farmer is considered and despite the differences between farmers. In fact, the selection of the breeder in each location cluster more closely with the breeder selection done in Tel Hadya and Breda than with the selection done by any farmer. The selections of the host farmer did not show any particular similarity or dissimilarity pattern which makes them distinct from those of the other farmers. This would suggest that the relationships between centralized and decentralized selection and between participatory and non participatory, are not affected by the choice of a particular farmer as host farmer, at least in five of the nine locations.

The lines most frequently ranked among the best 15 in the five locations where group selection was conducted are listed in Table 14 together with the number of times each line was included in the first 15 (Sel) and the mean ranking (Mean) obtained by averaging the ranks of each line with 15 being the rank of the best, 14 the rank of the second best, and so on.

In total 42 different lines were ranked among the best 15 in the five locations. The majority (38 or 90%) were ranked within the best 15 only in one or two locations. Line 118, a white-seeded line derived from a cross with a Syrian landrace (SLB 34-65/Arar) was ranked in the best 15 in four of the five locations, while lines 148, also derived from a cross with a Syrian landrace, and 20 and 40 (two of the eight local varieties used in the trials) were ranked in the best 15 in three of the five locations.

Table 14. Lines ranked highest by groups of farmers in five locations, with the number of times each line was included in the first 15 (Sel) and the mean ranking (Mean) obtained by averaging

the ranks of each line with 15 being the rank of the best, 14 of the second best, and so on. In bold are the lines selected by the individual (host) farmers at the same location and in the bottom line (Ind) is the frequency of lines selected both by individual farmers and by the group of farmer at that location.

Sauran (09)				Al Bab (06)			Bari Sharki (08)			Baylonan (05)			Jum El-Aswad (04)		
Nr	Line	Sel	Mean	Line	Sel	Mean	Line	Sel	Mean	Line	Sel	Mean	Line	Sel	Mean
1	52	5	7.5	128	8	10.0	118	7	8.4	181	7	11.4	40	7	8.6
2	131	5	6.4	111	7	10.3	157	7	10.1	148	5	6.9	20	6	7.6
3	87	5	6.0	106	7	7.5	106	5	7.0	20	4	5.8	118	6	8.1
4	148	4	3.8	183	7	11.4	208	5	4.4	112	4	4.4	192	6	7.4
5	208	3	3.8	199	6	8.4	111	5	6.0	157	3	4.6	183	5	5.8
6	139	3	3.0	187	6	9.4	44	3	3.3	141	3	2.6	195	5	6.1
7	88	3	2.8	116	4	4.9	94	3	3.9	142	3	2.9	198	5	5.8
8	155	3	4.8	40	4	3.4	93	3	3.8	40	3	3.1	194	4	3.8
9	118	3	3.9	117	4	3.8	107	3	3.9	161	3	5.3	116	4	4.9
10	156	3	4.6	109	3	2.9	199	3	2.9	185	3	4.5	131	4	5.0
11	105	3	4.3	118	3	3.5	192	3	3.2	177	3	4.0	148	3	2.2
12	30	3	4.8	20	3	2.9	105	3	4.2						
13				155	3	4.4	104	3	3.1						
14				154	3	2.5	95	3	3.6						
Ind	0.30			0.73			0.64			0.67			0.67		

Effective selection criteria

The data recorded on a number of plant characteristics were used to determine whether the groups of lines selected by the breeder or the farmers in either the farmers' fields or the experiment stations differed significantly from the initial population of 208 lines. The results are shown in Table 15 for those traits which were fully analyzed at the time of writing this report. The comparisons are based on a t-test for groups of unequal size, and the data in the Table are the number of times the difference between the mean of the selected lines was significantly different from the population

mean. In the case of the selection by the breeder in Tel Hadya and Breda the presence of a significant difference is indicated by a Y (yes).

Table 15. Effective selection criteria used by farmers and breeder: number or presence of significant differences between the mean of the selected lines and the population mean (test for groups of unequal size)

Trait ^a	Expression	Farmers' selection			Breeder's selection		
		his own field	Tel Hadya	Breda	farmer's field	Tel Hadya	Breda
Growth habit	erect	2	0	2	0		
	prostrate	2	1	0	3		
Growth vigor	poor	0	1	0	0		
	good	2	0	4	3		
Color	dark	0	3	0	1	Y	
	pale	1	0	0	0		
Heading	earlier	0	0	0	0		
	later	1	1	3	0		
Lodging	resistant	1	9	0	0	Y	
	susceptible	2	0	2	4		
Tillering	higher	0	0	4	1		
	lower	0	2	0	0		
Tillering in BR	higher	1	0	1	0		
	lower	1	1	0	0		
Height ^b	taller	4	0	5	4		
	shorter	0	1	0	0		
GY farmer field	higher	6	2	3	6	2	
	lower	0	0	1	0	0	
GY Breda	higher	2	0	9	0		Y
	lower	1	0	0	0		
GY Tel Hadya	higher	2	8	0	3	Y	
	lower	2	0	3	0		
BY farmer field	higher	5	1	2	4	2	
	lower	0	1	1	0		
BY Breda	higher	0	0	3	0		
	lower	0	0	0	0		
BY Tel Hadya	higher	1	6	0	1	Y	
	lower	0	0	0	0		

^a measured in Tel Hadya unless indicated otherwise; GY = grain yield; BY = total biological yield

^b measured at the selection site (plant height was not measured in Melabya).

The most remarkable result is that farmer selection was very effective in identifying high yielding entries both in their fields (the lines selected in 6 out of the 9 locations had a significantly higher average grain yield than the 208 lines) and even more so in the experiment stations (the lines selected by all the nine farmers in Tel Hadya and by eight of the nine farmers in Breda locations had a significantly higher average grain yield than the 208 lines in the two stations). The higher effectiveness on station could be explained by the higher precisions of the trials, but one should also remember that modalities of selection were not the same. The breeder's selection were also significantly higher yielding than the population mean in 6 out of the 9 farmers fields and in the two experiment stations. The lines selected by the farmers and by the breeder in the 9 locations never differed significantly in grain yield (Table 16).

Table 16. Grain yield (kg/ha) and Total biological yield (kg/ha) of the lines selected by the farmers and by the breeder in each of the nine farmers' fields.

Location (code)	Grain yield			Biological yield		
	Farmer	Breeder	P ^a	Farmer	Breeder	P ^a
Ibbin (01)	4615***	3971***	n.s.	10687**	9686***	n.s.
Ebla (02)	3498*	3199**	n.s.	8743	8233	n.s.
Tel Brak (03)	4235	4020*	n.s.	8729*	8036	n.s.
Jum El-Aswad (04)	2049*	1724**	n.s.	10535**	8429*	n.s.
Baylonan (05)	454*	324	n.s.	3198	2816	n.s.
Al Bab (06)	649***	488***	n.s.	2272***	1787***	n.s.
Melabya (07)	915	920***	n.s.	4127**	3246*	n.s.
Bari Sharki (08)	1366*	1129	n.s.	5276	4708	n.s.
Sauran (09)	2561	2654	n.s.	6796	7257	n.s.
Breda (10)						
Tel Hadya (11)						

* P<0.05; **P<0.01; ***P<0.001 relative to the comparisons with the population mean

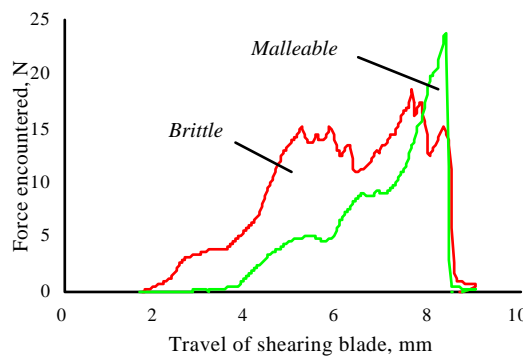
^a comparison between breeder's and farmers' selections based on t-test for samples of unequal size.

COMPONENT 5: MEASUREMENT OF FARMERS' SELECTION CRITERIA OR GRAIN AND STRAW QUALITIES

One of the methods farmers use to estimate the feeding value of barley straw is tactile; they feel the texture of straws between their fingers. To quantify farmers' knowledge, we have been using an

SMS Texture Analyser⁵ (TA) to develop objective measurements of texture. The TA, which electronically records characters of straws, was used to quantify shearing and bending resistance of the straw of the 208 barley lines.

From bundles of whole plants sampled before grain harvest, ten plants were taken at random. The heads of these plants were removed, kernel number and spike length measured, then a *bend* test was performed. The bend test described elsewhere was simplified, so that ten of the lowest whole internodes (LWI) or ten peduncles (PED) could be tested simultaneously. To bend internodes supported at points 50 mm apart by a distance of 4 mm would have caused irreversible weakening; instead, they were bent by only 1 mm, and were bent three times to ensure that measurements were consistent. Since the peduncles or LWI were not absolutely straight and not contact all of them measurement of the point when the mm from its first contact, the lowest point of travel 1.0 mm.



therefore the *finger* could simultaneously, *inelasticity* was made from finger had descended 0.6 and was continued until of the finger, usually

Shearing tests were performed on LWI only, on ten separate internodes (five LWI in each of two runs). The stem diameter was measured as the distance between the start of the curve (actually, where the force encountered was 1 Newton) and 8 mm, divided by 1.5 to allow for the 60° shape of the V-notch. The shearing energy was the area (force × distance) under the curve.

The shape of different shear test graphs (Figure 13) suggests that some internodes are brittle, absorbing energy as a series of fracture peaks, and that others are malleable, not absorbing energy until the tissues of the internode were fully compressed by the V-shaped notch. A simple way to distinguish between these two types of graph was use a Texture Expert macro to count the number of force peaks in the graph that were taller than 1 N, a measurement called *brittleness*.

⁵Stable Microsystems Ltd, Godalming, Surrey, U.K., Model TX-TA2 (5 kg).

Figure 13. Genotypes with brittle and malleable shearing curves are distinguishable by the number of force peaks. Ibbin site.

Wetness of site

In general, genotypic coefficients of variation (CV) of traits were larger in the wetter sites than in the drier sites (Table 16). In wet sites, genotype CVs ranged from 0.28 for shearing energy down to 0.08 for diameter; in dry sites, they ranged from 0.18 to nil. CVs between sites were up to four times greater than CVs between genotypes; classification of sites into "wet" and "dry" reduced the between-site CV for diameter and shearing energy, but not for inelasticity or brittleness.

Relationships with diameter

Some relationships between LWI shear energy or peduncle bending force and LWI diameter are shown in one dry site (Al Bab) and one wet site (Ibbin) (Figure 14). Shear energy tended to increase with the square of stem (LWI) diameter. In the study of Arta and *H. spontaneum* reported elsewhere, shear energy was highly correlated with the ratio of stem mass to length, itself proportional to the square of diameter.

Table 16. Sources of variation of mechanical characteristics in 208 barley genotypes grown in village fields in eight locations

Test	Mean	SD _{genotype}	Sd _{site}	SD _{error}
Inelasticity of lowest whole internode, N/mm bend	1.06	0.198****	0.797****	0.783
within four drier sites	1.07	0.092ns	1.094****	0.991
within three wetter sites	1.04	0.108□	0.339****	0.451

Inelasticity of peduncle, N/mm bend	0.51	0.101***	0.412****	0.403
within four drier sites	0.49	0.000ns	0.520****	0.504
within three wetter sites	0.53	0.120****	0.319****	0.227
Diameter of LWI, mm	2.54	0.189****	0.318****	0.203
within four drier sites	2.27	0.138****	0.159****	0.184
within four wetter sites	2.81	0.235****	0.112****	0.213
Shearing energy of LWI, mJ	48.5	11.55****	16.64****	20.32
within four drier sites	41.1	7.22****	4.98****	18.61
within four wetter sites	56.2	15.88****	11.48****	19.42
Brittleness of LWI, number of peakş	2.04	0.205****	0.361****	0.493
within four drier sites	1.85	0.103□	0.332****	0.461
within four wetter sites	2.24	0.295****	0.278****	0.511
Shearing energy / LWI diameter□, mJ/mm□	15.6	1.23**	5.05****	5.84
within four drier sites	16.6	1.56□	7.28****	7.42
within four wetter sites	14.4	1.15***	1.97****	3.38

□, *, **, ***, **** denote statistical significance at $P < 0.1, 0.05, 0.01, 0.001, 0.0001$, estimated using SAS PROC GLM.

□SD denotes the square root of variance components estimated using SAS PROC VARCOMP. Brittleness is indicated by the number of force peaks taller than 1 Newton.

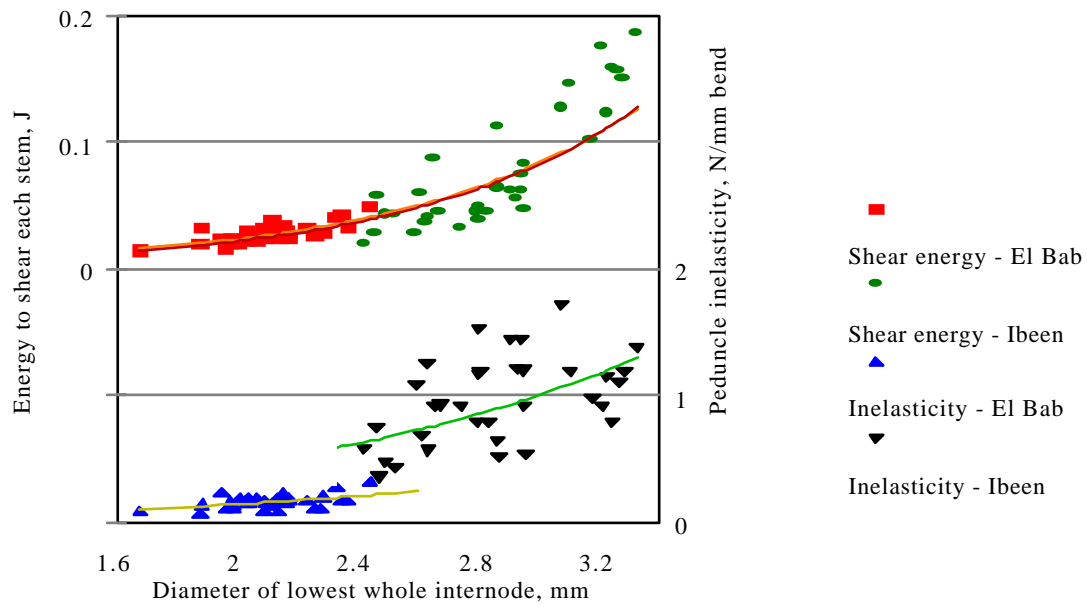


Figure 14. Relationship between shear energy, or inelasticity, and stem diameter at two contrasting sites.

Table 15. Rainfall distribution in the nine farmers' fields and in the two research stations (Breda and Tel Hadya).

Location	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
Ibbin	26.4	38.7	14.8	103.5	36.5	28.8	70.0	113.8	3.7	0.0	436.2
Ebla	2.0	29.5	27.0	119.0	72.0	25.0	72.0	110.5	2.5	0.0	459.5
Tel Brak	7.0	6.0	5.5	124.5	0.0	20.0	68.0	30.4	17.0	0.0	278.4
Jum El-Aswad	0.0	0.0	29.0	67.0	37.5	74.0	38.0	38.5	0.0	0.0	284.0
Baylonan	0.0	0.0	17.0	55.1	80.0	9.6	20.5	10.7	0.0	0.0	192.9
Al Bab	0.0	21.0	13.0	138.0	27.0	33.0	56.0	62.0	0.0	0.0	350.0
Melabya	0.0	0.0	7.9	115.8	20.3	36.0	37.3	13.8	10.0	0.0	241.1
Bari Sharki	0.0	23.0	11.0	56.0	64.5	12.0	58.0	15.0	8.0	0.0	247.5
Sauran	1.0	48.0	18.5	53.0	56.2	27.5	61.0	36.0	2.0	0.0	303.2
Breda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tel Hadya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0