Farmers' Performance Criteria for New Barley Varieties and their Diffusion through Farmer-to-Farmer Seed Distribution

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Executive Summary

Barley, mainly the two local landraces ‘Arabic Abiad’ and ‘Arabic Aswad’, covers about 1.38 million ha of cultivated land in Syria. The average yield of these landraces is less than 1 t/ha. Barley breeders have developed several promising new varieties with 20% higher yields than local landraces, without the need for additional inputs. For these new varieties to be adopted, the seed should be easily and widely available to farmers. The present study evaluated the role of farmer-to-farmer seed exchange in the distribution of new varieties, by tracing the flow of seed from 52 farmers in 24 villages in Syria. Each farmer was supplied with 100-200 kg of seed of the new barley varieties in the 1994/95 season, and the ensuing distribution traced for five years. The reasons for farmer acceptance or rejection of promising new varieties in different agro-ecological zones, and the extent to which farmer-to-farmer distribution of the seed was autonomous, were examined.

Most of the farmers involved had collaborated with the ICARDA barley improvement program, either through on-farm trials or by attending field days. One released variety (‘Arta’) and four promising new barley varieties (‘Rihane-03’, ‘Zanbaka’, ‘Tadmor’, and ‘WI2291’) were distributed in the first year. Some farmers selected more than one variety and others chose only the one considered most suitable for their environment. Farmers grew the new varieties in the same way as their local barley, without supervision from ICARDA or national extension agents. The total number of farmers in the study rose to 206 in the last year (1998/99), but those receiving new seeds each year declined after a peak in 1996/97.

Growers were divided into two types: ‘new growers’ who grew the varieties for the first time, and ‘adopters’ who grew the varieties more than once. The adoption rate peaked at 75% in the second year and then declined slowly, with no significant difference between agro-ecological zones. In the first year about 30% of growers grew more than one new variety, and some grew up to four. This dropped to only 4% in the last year, suggesting that they tested several before selecting the best new varieties. This suggests that farmers retain some traditional varieties to reduce losses in bad years. Although some farmers discontinued the new varieties, they did not necessarily reject them, since about 35% stopped growing

barley altogether, choosing to introduce other options, such as fruit trees, particularly on stony and shallow soils. The average grain yield for the new barley varieties was higher than the local landraces in all agro-ecological zones; the average increase was 60%, and range 53-160%.

Farmers' opinions of new varieties they saw or grew themselves were important since this reflected their experience and judgment. Higher yield was important, and was most frequently cited as the reason for growing 'Arta', 'Rihane-03', and 'Tadmor'. The lodging resistance of 'Rihane-03', that also had good adaptation to relatively high rainfall, was highly valued. Many farmers in drier areas believed good plant height was important, and that it reduced the risk of crop failure in a dry year.

On average, farmers sold 66% of grain as feed, and 4% as seed; they retained 13% to feed sheep, 7% for other uses, and 10% as seed for the next season, therefore, barley is primarily a cash crop in this region. Grain of the new varieties sold at similar prices to landraces as feed, but at higher prices when sold as seed.

The high adoption rates emphasized the importance of farmer participation in evaluating new varieties and distributing seed. Farmer-to-farmer seed transfer is a viable option to disseminate new varieties of cereals such as barley, especially when seed companies have not met local demand. Community-level seed technology is needed to guarantee quality and to establish trusted local seed experts as key participators in crop improvement programs, to ensure a constant flow of new germplasm into communities.

Contents

Introduction

Adoption of new crop varieties has been much slower in dry than in the more favorable agricultural areas, due to the difficulty in breeding for greater environmental variability. In Syria, experiments indicate that new barley varieties can have 20% greater yields compared to local landraces, without additional inputs; however, farmer uptake of these varieties has been slow. The 1.38 million ha of barley cultivated in Syria (average 1996-2005) is largely based on two local landraces, white-seeded 'Arabic Abiad' and black-seeded 'Arabic Aswad'[1]. For a number of reasons, barley yields in Syria are low. Firstly, they are dependent on weather conditions, especially the amount and distribution of rainfall. There is a high correlation between rainfall and barley yield (r = 0.82; Mona 1986) with large variation between seasons (Ceccarelli and Grando 2007). Secondly, all farmers use local and not improved barley varieties. Thirdly, soil fertility is poor in the dry areas where barley is the dominant crop. Fourthly, minimum fertilizer inputs are used, since many farmers regard high applications as too risky in dry areas.

The continued use of local landraces can be explained by the failure of the formal seed supply system in these environments. Generally, formal seed supply systems work very well at producing large quantities of few varieties for large areas. However, farmers in the dry areas often use a relatively large number of varieties, and mixtures of improved varieties with local landraces, to minimize production risk and disease incidence. Different varieties are necessary in specific socioeconomic and agro-ecological zones (Sperling et al. 1996); recently a direct relationship between genetic diversity, farm productivity and risk management was shown (Di Falco and Chavas 2006), implying that no single variety will cover a substantial area. Therefore, diffusing new crop varieties into marginal areas requires better understanding of the criteria used by farmers to assess variety performance, and the identification of alternative mechanisms of diffusion. In other regions, farmer-to-farmer seed exchange has been effective in diffusing modern varieties to small farmers in marginal environments, where formal seed supply systems were not effective or efficient (Almekinders et al. 2007). However, there is little knowledge of the informal seed supply

[1] 'Arabic Abiad' is common in more favorable environments (annual rainfall 250-400 mm) and 'Arabic Aswad' in harsher environments (annual rainfall < 250 mm).

sector and its operation in the West Asia and North Africa (WANA) region, and consequently few publications. Diffusion theory stresses that decentralized communication channels, through which knowledge and information are disseminated via informal networks, are essential to behavior change (Rogers 1983). Farmer-to-farmer seed exchange is one decentralized communication channel. Studies elsewhere (Cromwell 1990; Ndjeunga, *et al*., 2000)) have found that farmer-to-farmer seed exchange is an effective means of diffusing new varieties to smallholder farmers where formal seed systems were unable to cover. These studies concluded that informal seed systems are the main source of seed for smallholder even in situations where formal seed systems have large number of seed outlets, and that the diffusion of new crop varieties are done primarily through informal seed systems. The main purpose of the present study was to determine the extent of new barley variety diffusion through farmer-to-farmer seed exchange, farmers' performance criteria of new varieties, and the factors affecting variety adoption or rejection.

2. Research Methods

Five varieties developed by the International Center for Agricultural Research in the Dry Areas (ICARDA) barley breeding program were used; 'Arta', 'Rihane-03', 'Zanbaka', 'Tadmor', and 'WI2291'. The characteristics of these varieties are as follows:

'Arta'

'Arta' is white-seeded and derived from a single head collected from a field of 'Arabi Abiad' in the Haurani plateau in Sweida province. It was evaluated on-station (1984/85 to 1987/88) and then in on-farm verification trials in Syria's Agricultural Stability Zone 2[2] for

[2] Syria is divided into five agricultural stability zones according to average and variability of rainfall.

Zone 1: annual rainfall > 350 mm, divided into two areas:
a. annual rainfall > 600 mm where rainfed crops could be successfully cultivated.
b. annual rainfall 350-600 mm and > 300 mm during two-thirds of years. It is possible to get two seasons every three years. The main crops are wheat, legumes, and summer crops. This zone occupies 15% of Syria.

Zone 2: annual rainfall of 250-350 mm and > 250 mm during two-thirds of years. It is possible to get two barley crops every three years. Wheat, legumes, and summer crops could also be cultivated. This zone is 13% of Syria.

Zone 3: annual rainfall of 250 mm and > 250 mm in half of the years. It is possible to get one or two growing seasons every three years. The main crop is barley, but legumes can be cultivated. This zone accounts for 7% of Syria.

Zone 4: annual rainfall of 200-250 mm with > 200 mm in half of the years. It is suitable for barley or for permanent grazing. This zone is 10% of Syria.

Zone 5: includes desert and steppe, not suitable for rainfed crops and covers 55% of Syria.

four years (during 1988/89 to 1993/94). In on-farm trials Arta had an average yield 21% greater than that of ‘Arabi Abiad’. It was officially released in 1994 as ‘Arabi Abiad Mohassan’. ‘Arta’ is high tillering, with a long spike and large grain. It has vigorous winter growth, good cold tolerance, and distinctive blue aleurone. It performs well in Zones 2 and 3, but in Zone 3 it is often very short under drought conditions.

‘Rihane-03’

‘Rihane-03’ (Atlas46/Arivat//Athenais) is a six-rowed variety developed in extensive multi-location on-farm testing by ICARDA, and has 11% greater yield than ‘Arabi Abiad’. ‘Rihane-03’ has been released in Iraq, Iran, Lebanon, Algeria, Tunisia, Morocco, and Spain, but not in Syria.

‘Zanbaka’

‘Zanbaka’ is a black-seeded cultivar derived from a single head collected in Hasakeh Province. It has been evaluated on-station (1984/85 to 1988/89) and then in on-farm verification trials in Zone 3 for four years (1989/90 to 1992/93). In the evaluation years ‘Zanbaka’ had 1.5% greater yield than ‘Arabi Aswad’; however, in participatory breeding trials ‘Zanbaka’ had 17% greater yield. The most attractive trait of ‘Zanbaka’ is height, as it is about 10 cm taller than ‘Arabic Aswad’ in dry conditions; farmers consider this very important as it allows combine harvesting even in dry years. ‘Zanbaka’ appears well adapted in the provinces of Raqqa and Hasakeh. It has not been officially released.

‘Tadmor’

Similarly to ‘Zanbaka’, ‘Tadmor’ is a black-seeded cultivar derived from a single head, in this case collected in Raqqa Province. It was evaluated on-station in 1984/85 and in on-farm verification trials in Zone 3 (1985/86 to 1998/99) with 3.6% greater yield than ‘Arabi Aswad’. Similar to ‘Zanbaka’, yields of ‘Tadmor’ were 19.3% greater in participatory breeding trials. ‘Tadmor’ appears particularly well adapted in the Hasakeh province, but has not been officially released.

‘WI2291’

‘WI2291’ is a white-seeded cultivar produced at the Waite Institute in South Australia from the cross CI3576/Union*2. After the on-station evaluation, it was further evaluated in on-farm verification trials in Zone 3 (1985/86 to 1988/89) with average yields 5% greater than ‘Arabi Aswad’ and 6.5% greater than ‘Arabi Abiad’. ‘WI2291’ is particularly well adapted in Zone 3 of Hama Province, but has not been officially released.

In the 1994/95 season ICARDA distributed seeds of these varieties to 52 farmers in five provinces (Aleppo, Idleb, Hama, Raqqa, and Hasakeh) covering three stability zones (Zones 1, 2, and 3) in Syria. The majority of these farmers had collaborated with the Barley Improvement Project through on-farm trials in their fields, or learned about these varieties at farmer field days. Some farmers selected more than one variety; others chose only one that they thought suitable for their environment. Farmers planted the new varieties using their usual practices and inputs, without supervision from ICARDA or National Extension Agents. This study was conducted for five years (1994/95-1998/99), and the diffusion of new varieties among farmers and villages, and the farmers’ criteria for choosing successful new barley varieties were recorded.

The initial 52 farmers (who received seed from ICARDA) and others who obtained seed of a new variety from the 52 farmers (either directly or through other farmers in following years) were surveyed every year from 1994/95-1998/99. Not all farmers grew barley every year; some farmers temporarily stopped growing new barley varieties for reasons unrelated to performance, such as crop rotation or shortage of seeds In the following year 45 new growers (who received new varieties from the 52 farmers) were included, making a total of 97 farmers interviewed (Table 1). There were 149 farmers in the third year, 186 in the fourth, and 206 in the fifth (the last) year. The farmers were visited once a year at the end of the planting season and surveyed, using a questionnaire addressing, for each new barley variety:

- source and price
- area planted and harvested
- yield, production, and disposal

- amount of seed used
- names and addresses of new farmers who purchased seed
- reasons for retaining seed for future planting
- reasons for selling as feed
- soil type, previous crop, and fertilizer added
- previous and planned subsequent crops/varieties
- farmer's opinion of variety.

In the last year of the study, there was a second questionnaire survey focused on farmer and farm characteristics, such as age and education of household head, family income, farm size and barley area (new varieties and local), livestock numbers, and machinery ownership (Table 2).

Table 1. Number of farmers who received new barley varieties in the sample

	Years					
Agro-ecological zones	1994/95	1995/96	1996/97	1997/98	1998/99	Total
Zone 1	1	12	25	28	28	**94**
Zone 2	37	58	86	115	134	**430**
Zone 3	14	27	38	43	44	**166**
Total	**52**	**97**	**149**	**186**	**206**	**690**

Table 2. Socioeconomic characteristics and farm resource of farmers in the sample

	Year					
	1995	1996	1997	1998	1999	Average
Age of household head	51	50	52	52	52	52
Number in the family	13	6	10	11	11	10
Household income (%)						
Crop	58	58	43	59	52	54
Livestock	5	5	4	3	8	5
Off-farm	37	53	38	40	39	41
Land (ha)						
Farm size	47	10	22	10	14	23
Rainfed area	35	6	9	7	10	15
Suppl. irrig. area	7	7	2	7	2	2
Full irrig. area	5	5	2	6	1	2
Livestock (head)						
Sheep	29	4	9	12	12	13
Goats	1	0	1	2	1	1
Cows	1	2	2	6	4	3

Tractor ownership (%)	48	33	34	35	42	37
Education (%)						
None	23	23	31	37	38	32
Preliminary	12	19	15	12	12	14
High School	37	35	35	37	36	36
BSc	29	24	19	16	15	18

The survey data were entered into a computerized database system using Statistical Package for Social Sciences (SPSS). Several analysis procedures were used, including monitoring of farmer-to-farmer seed exchange over five years through comparing the repeated yearly interviews; descriptive analysis and cross-tabulation to determine the characteristics of farmers involved in seed distribution, their assessment of new varieties, and factors affecting their adoption. Quantitative analysis of adoption of new varieties was also used to identify key elements influencing adoption behavior of farmers.

3. Formal seed sector and barley based farming system in Syria

There are formal and informal systems in the seed supply sector, geared towards different crops and farmers. The formal sector includes public and private seed suppliers. In Syria, the General Organization for Seed Multiplication (GOSM) almost exclusively produces the seed of the major crops; wheat, barley, lentil, chickpea, beans, maize, potato, sugar beet, and cotton. GOSM is a public sector organization established in 1975 by the Ministry of Agriculture. The objectives of GOSM are to: organize formal seed multiplication of released varieties and establish seed processing and storage facilities; market and distribute seed directly or through other government organizations; provide training on seed production and advisory services for farmers. Private firms produce and import seed of vegetables, ornamentals, and crops for which GOSM does not produce seed.

Seed requirements of field crops are generally met through domestic production. The government determines seed prices, and certified seed is sold at 60% above the grain price to recover production and processing costs (Radwan 1997). GOSM is responsible for seed quality control, performed at stages during seed production, processing, storage, and before distribution.

The formal seed supply system in Syria does not cover all national seed requirements in all years. Seed sales by GOSM in relation to Syria's requirements during 1990-94 are summarized in Table 3. The formal seed system is successful producing large quantities of seeds for some crops with seed replacement rate[3] exceeding 100% for cotton, about 70% for wheat, and about 5% for barley. Although the seed replacement of priority crops is high, farmers do not always have enough seed of the proper variety and so use whatever variety is available, indicating some failure of seed supply. However, crops like barley that are grown in marginal environments, in Syria and elsewhere, are in a more disadvantageous supply situation (Almekinders et al. 2007).

The failure of the formal seed sector to provide for crops like barley may be for several reasons. One is reluctance of farmers to pay a sufficient price to cover new seed costs, related to the expected yield gain in comparison to local varieties. Yield improvement depends on the farming system and understanding the current system in Syria is essential to explain this failure of formal seed supply.

Table 3. Seed sales by General Organization for Seed Multiplication (GOSM) compared to Syrian national requirements, 1990-94 (Radwan 1997)

Crop	Seed sales ['000 t]				
	1990	1991	1992	1993	1994
Wheat	146 (72)	132 (65)	163 (69)	163 (67)	174 (66)
Barley	12 (6)	5 (2)	10 (4)	14 (7)	10 (6)
Faba bean	0.5 (20)	0.8 (28)	2 (105)	1 (52)	0.1 (4)
Chickpea	0.7 (20)	0.2 (6)	0.9 (22)	0.6 (17)	0.3 (11)
Lentil	1.3 (10)	1.2 (8)	2.3 (17)	2 (12)	1.6 (10)
Cotton	25 (161)	25 (142)	29 (195)	29 (148)	28 (137)

Figures in parentheses show sales as a % of requirement

Barley is the most common crop in Syria and covering about 1.4 million ha, or 25% of cultivated area. Virtually all barley is rainfed, and most is in Zones 2 and 3 of Aleppo, Idelb, Hama, Homs, Raqqa, and Hasakeh Provinces (Figure 1).

Barley in Syria is grown under the following conditions:

- ***Marginal environments***: agricultural policy has encouraged farmers in drier areas to change from wheat to barley cultivation, since it has better adaptation in these areas

[3] The ratio of seed supplied by the formal seed supply sector to the theoretical national seed requirement (FAO 1999).

(Somel 1987). The barley/livestock system[4] is adjacent to the dry steppe, and produces most barley with an annual rainfall of 200-350 mm, where livestock production is the dominant enterprise, principally sheep and goats, and farmers derive most income from dairy products, meat, and wool (ICARDA 1989). When farmers in the dry areas obtain a greater source of water, they move from rainfed to irrigated crops (e.g. in summer: cotton, potatoes, sugar beet, and maize; and irrigated wheat in winter), with wheat replacing barley. In some wetter environments barley is the marginal crop that is usually grown on shallow soils specifically for livestock feed.

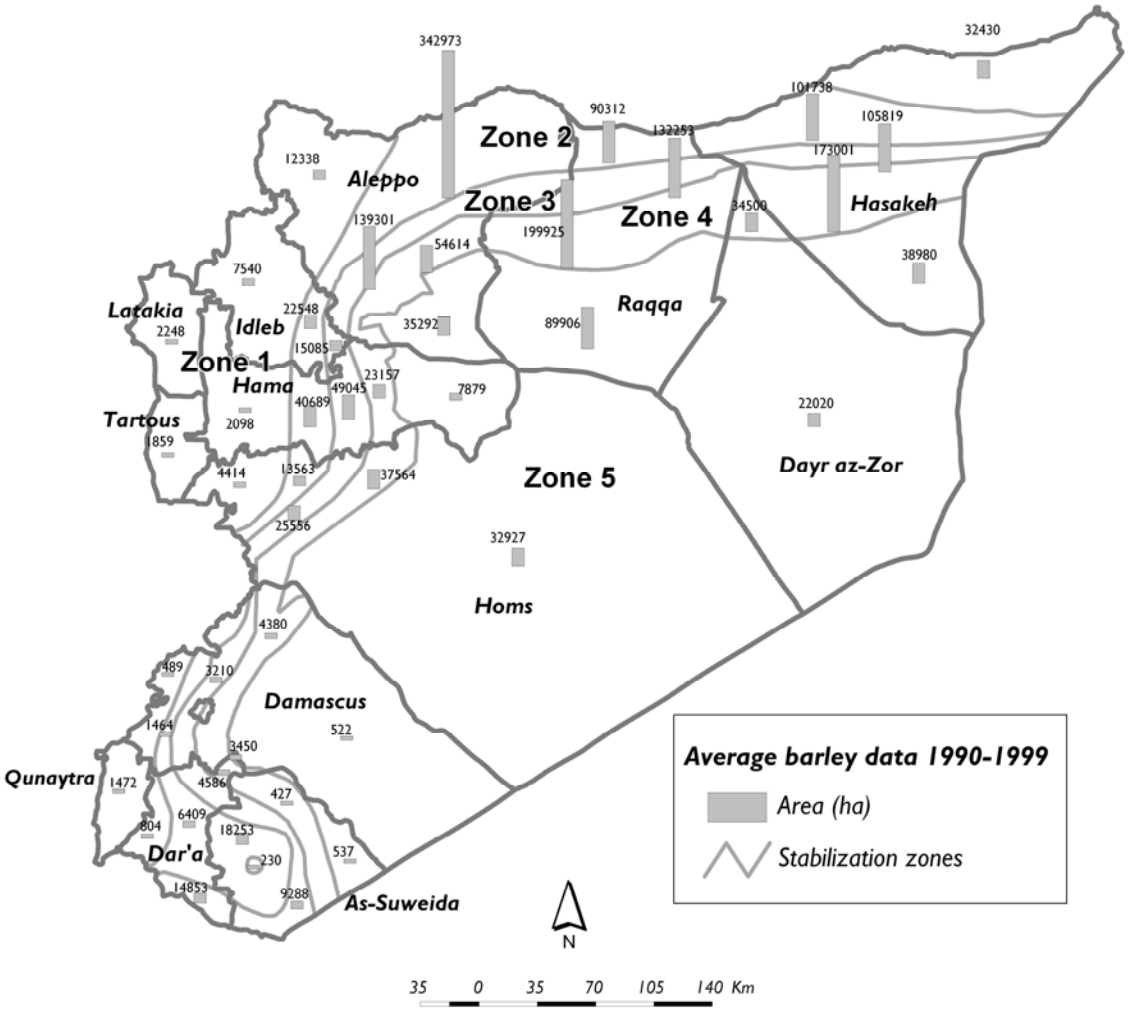

Figure 1 Average barley areas by provinces and stability zones.

[4] Farming systems in the WANA region are characterized as: deserts, steppe and native pastures, the barley/livestock system, the wheat-based system, and highlands (ICARDA 1989).

- ***Comparatively low input levels***[5]: producers are not willing to spend a lot for barley cultivation, they do not practice weed control since weeds in the dry areas are not perceived as a real problem. Many farmers have replaced fallow/barley rotation with continuous barley.
- ***Not always harvested***: about 25% of farmers grazed their barley at the vegetative stage. Some have a strategy to graze out mature barley, instead of harvesting in dry seasons; based on an expectation of greater direct grazing value (Mazid and Hallajian 1983).
- ***Inherent low yields and variability***: farmers generally expect low yields, although expectations are higher in Zone 2 than Zone 3. The numbers of good, normal, and poor years differ between zones; farmers in Zone 2 expect more good years and less poor years than in Zone 3. There is a large variation among yield expectations in good, normal, and poor years, and over the long term in both zones. The expected average barley yield in poor years is very low (262 kg/ha), and farmers expect this yield in 3 out of 10 years – the 30% probability of such low yields is a significant risk in barley production.
- ***Production is highly mechanized***: as tillage has become more mechanized, continuous barley production has become more common, despite being detrimental to yield (ICARDA 1989). Where farms are large or animal populations low, barley is a cash crop, with the stubble rented to graze migrating flocks. With increased demand for livestock products, barley cultivation has expanded to more marginal lands in the steppe.
- ***Local varieties dominate***: nearly all barley producers use local varieties (Mazid 1994). The local black-seeded landrace 'Arabic Aswad' is dominant in northeastern Syria. In western Syria, 'Arabic Aswad' and a local white-seeded landrace 'Arabic Abiad' are available. Most farmers supply their own seed, but when they cannot harvest barley in very dry seasons, they usually purchase seed from other farmers or local markets.

[5] Average phosphate applied is about 45 kg/ha P_2O_5, if a farmer used it. Urea and ammonium nitrate are the most common nitrogen fertilizers. Average nitrogen application is 23 kg N/ha at planting time, and 30 kg N/ha as top dressing. Average seed rate was 180 kg/ha, which is higher than recommended.

With the range of farming circumstances, one or two new varieties cannot cover the large barley area. This is due to high spatial and temporal variability of these dry environments, the poor natural resources of dry areas (particularly soil fertility), and low input use. In the public and private formal seed supply sectors, it does not cover costs or make profits producing small amounts of many varieties in response to variability. Farm yield gains from new varieties are not sufficiently high to justify purchase from the formal sector. Partial budget analysis for using new barley varieties from the formal sector shows that an expected yield increase of 20% does not cover the additional costs plus a minimum acceptable return to investment of 40%, except in Zone 1 (Table 4). Risk is another factor that does not encourage farmers in harsh environments to adopt new agricultural technologies. The strategy of planting barley that is not meant to be harvested every year or to maximize profit, but to produce feed, means expensive seed cannot be justified. The high probability of getting lower than 1 t/ha due to drought and current low yields, particularly in drier zones (Table 5), do not encourage the formal sector to produce and supply seeds of new barley varieties. In summary, the farmers are not willing to purchase new seeds every year because of high seed prices, low expected yield increase and production risk in dry conditions. Therefore formal seed supply system in Syria has not been successful to supply barley seeds to growers.

Table 4. Estimated minimum increases in barley yields to cover additional costs of seed in the formal seed sector

Zones	Average seed rate (kg/ha)	Additional costs of seeds (SL/kg)	Additional costs due to new seeds (SL/ha)	Calculated for break even & 40% return (SL/ha)	Market barley price (SL/kg)	Min. increase in yield required (kg/ha)	Average barley yield (kg/ha)	Expected increase in yields at 20% level (kg/ha)
1	240	5.5	1320	1848	7	264	1603	321
2	200	5.5	1100	1540	7	220	952	190
3	150	5.5	825	1155	7	165	492	98
4	120	5.5	660	924	7	132	359	72

Table 5. Barley yields during 1985-1999

Zones	Barley yield (kg/ha)				Yield probability (%) < 1000 kg/ha	Yield probability (%) < 500 kg/ha	Estimated average area (%)
	Min	Max	Mean	Std. Deviation			
1	475	2240	1603	497	13	7	2.7
2	160	1644	952	366	60	13	34.8
3	55	1482	492	356	93	53	30.5
4	11	1577	359	398	93	73	31.0
5	12	1202	260	316	93	87	1.0
Average	88	1529	620	353	87	40	100.0

4. The informal barley seed supply sector

4.1 Seed networks

The informal seed supply sector includes indigenous strategies and networks used by farmers to improve their seed quality and quantity. In the informal sector, farmers keep seed of a new variety for the next season. Those who have seen or heard through other farmers of the new varieties, purchase seeds from other farmers if they consider the new varieties are better than local varieties.

In the present study, the movement of new barley varieties among farmers had more than one pattern: some farmers did not sell any seed, others sold seed only in their second year, and some sold seed to other farmers for more than one year. The initial 52 farmers, who received seeds of new barley varieties, transferred these varieties to another 156 farmers during the study. Figure 2 shows the distribution networks of barley varieties in villages for the five years of the study.

The codes in Figure 2 are read backwards. For example, F14.16.2 means the second farmers who received seeds from farmer No.16, who obtained seeds from farmer No.14 of the original 52 farmers. Similarly, F14.3.1 indicates the first farmer who obtained seeds from farmer No.3, who in turn obtained seeds from farmer No. 14 of the original farmers. On the other hand, some original farmers distributed the seed in more than one year, for example farmer No. 52 distributed seed to farmer F52.1 in 1995/96, but he did not distribute any seed during 1996/97-1997/98, he again distributed seed to farmer F52.2 in 1998/99.

Figure 2. Farmer-to-farmer barley variety distribution networks in 1994/95-1998/99 growing seasons

1994/95	1995/96	1996/97	1997/98	1998/99
F1	F9.1	F11.1.1	F11.1.2	F11.1.1.1
F2	F9.2	F11.4.1	F11.1.3	F11.1.1.2
F3	F11.1	F11.4.2	F11.1.4	F11.1.1.3
F4	F11.2	F12.1.1	F11.1.5	F11.1.1.4
F5	F11.3	F14.3.1	F11.1.6	F11.1.7
F6	F11.4	F14.5	F11.6	F11.1.8
F7	F11.5	F14.6	F11.7	F11.1.9
F8	F14.1	F14.7	F11.8	F14.14.1
F9	F14.2	F15.1	F11.9	F14.16.1
F10	F14.3	F18.2	F14.5.1	F14.16.2
F11	F14.4	F19.1	F14.5.2	F15.2.1
F12	F18.1	F19.2	F14.5.3	F15.2.2
F13	F28.1	F19.3	F14.8	F15.2.3
F14	F28.2	F28.1.1	F14.9	F28.4.1
F15	F35.1	F28.1.2	F14.10	F30.1
F16	F35.2	F28.1.3	F14.11	F38.4.3
F17	F36.1	F28.1.4	F14.12	F38.4.4
F18	F36.2	F28.3	F14.13	F52.2
F19	F36.3	F28.4	F14.14	
F20	F36.4	F28.5	F14.15	
F21	F36.5	F28.6	F14.16	
F22	F36.6	F28.7	F14.17	
F23	F36.7	F28.8	F14.18	
F24	F36.8	F28.9	F14.19	
F25	F36.9	F28.10	F15.2	
F26	F36.10	F28.11	F16.1	
F27	F36.11	F36.1.1	F16.2	
F28	F37.1	F36.1.2	F16.3	
F29	F37.2	F36.1.3	F16.4	
F30	F38.1	F36.1.4	F19.4	
F31	F38.2	F36.1.5	F28.5.1	
F32	F38.3	F36.1.6	F36.16	
F33	F38.4	F36.1.7	F36.17	
F34	F39.1	F36.1.8	F36.18	
F35	F42.1	F36.1.9	F37.4	
F36	F42.2	F36.12	F44.6	
F37	F42.3	F36.13	F44.7	
F38	F42.4	F36.14		
F39	F44.1	F36.15		
F40	F44.2	F37.3		
F41	F45.1	F38.2.1		
F42	F45.2	F38.3.1		
F43	F45.2	F38.4.1		
F44	F46.1	F38.4.2		
F45	F52.1	F42.5		
F46		F44.2.1		
F47		F44.2.2		
F48		F44.3		
F49		F44.4		
F50		F44.5		
F51		F46.1.1		
F52				

Some farmers were more important in the seed distribution networks than others. These networks were informal and autonomous. Five farmers were the origins of stronger seed distribution networks; Farmers 11, 14, 28, 36, and 44. For example: Farmer No. 11 (F11) distributed seed directly to 9 (first generation) farmers; these 9 farmers distributed to 11 (second generation) farmers in the following year and so on, the total farmers in the transaction network reached 25 (Table 6). The generation in Table 6 indicates the sequence of farmers who get seeds from the five dominant networks.

Table 6. The distribution of new barley seed transactions in the sample farmers

Farmer no.	Number of farmers that acquired new seed				
	1st generation.	2nd generation	3rd generation	4th generation	Total
F11	9	11	1	4	25
F14	19	8	-	-	27
F28	12	6	-	-	18
F36	18	9	-	-	27
F44	7	2	-	-	9
Sub-total	65	36	1	4	106
Other farmers	-	40	10	-	50
Total	65	76	11	4	156
%	42	49	7	3	100

Table 7 summarizes the socio-economic characteristics and farm resources of the farmers that were important in seed distribution. Comparison between these major “seed-node” farmers and other farmers found significant differences only in farm size, tractor ownership, and income from crops. However, the “seed-node” farmers had more long-term connections with ICARDA through the Barley Breeding Program, and they had continuous access to the new varieties.

Table 7. Socio-economic characteristics and farm resources of farmers that were important in informal seed distribution

Seed distrib-utors	Zone	Age (y)	Farm size (ha)	Livestock numbers	Income (%)			Tractor ownership	Education
					Crop	Livestock	Off-farm		
F11	2	57	11	10	65	10	25	No	None
F14	2	32	125	0	60	0	40	Yes	B.Sc.
F28	2	65	35	61	95	5	0	Yes	High School
F36	1	54	80	0	80	0	20	Yes	High School
F44	3	50	100	0	100	0	0	No	Preliminary

Informal community-based seed networks are important sources of seed, and a few farmers and their associates formed the focal nodes for the bulk of the barley seed networks in the present study. Clearly these prominent figures in the informal seed sector are trusted individuals who are seen as reliable sources of new and pure seed, possibly through their association with outside organizations in research and extension. In the absence of effective formal systems these networks can develop effective community-based seed supply systems, which research and extension can support in order to disseminate information and seed of new varieties.

4.2 Seed sales

Of the farmers who grew new barley varieties, 10-24% sold some of their production as seed to other farmers from their own or other villages. Table 8 shows the amount and sources of seeds of new barley varieties. In the fifth year (1998/99) new varieties were about 27% of cultivated barley. Seed saved from previous season was used by 49% of farmers, and 37% purchased seed from neighbors, indicating the commercial importance of farmer-to-farmer seed distribution in diffusion of new varieties. By the fifth year, 14% of farmers received seed from ICARDA. The prices of new barley varieties sold for planting was higher than that sold for feed (Table 9), especially if the transaction was at village-level, as local farmers in the village were aware of local field performance of the new varieties, ‘seeing is believing’. The price of new varieties was similar to the local barley grain, however, only 3% of production of new varieties was sold as seed, but about 30% was retained as seed by the producers.

Table 8. Amount and source of seed (t) of new varieties planted by farmers

Item	Years					Total
	1994/95	1995/96	1996/97	1997/98	1998/99	
Variety						
Arta	8.5	21.2	30.5	13.5	13.8	87.5
Rihane-03	9.7	24.6	62.6	52.4	44.2	193.5
Zanbaka	9.0	12.5	0.4	0.5	4.5	26.9
Tadmor	13.5	26.1	26.2	31.2	33.4	130.4
WI2291	4.1	9.7	6.9	3.7	0.0	24.4
Zones						
1	1.4	5.5	6.9	6.2	5.1	25.1
2	21.6	55.5	83.8	75.0	59.3	295.2
3	21.9	33.0	35.9	20.1	31.5	142.4
Total of new varieties	44.8	94.1	126.6	101.3	95.9	462.7
Estimated amount of local varieties	228.1	218.0	261.3	261.1	279.2	1248.1
Estimated total seeds used	273.3	312.1	387.9	362.4	375.1	1710.8
New varieties used (%)	16.4	30.2	32.7	28.0	26.6	27.0
Sources of new varieties (%)						
ICARDA	100	7	8	9	14	
Neighbors	-	55	53	41	37	
Own seed	-	38	39	50	49	

Table 9. Average seed and grain sold and kept of new barley varieties during the five year study

Variety	Total production (t)	Seed sold	Seed kept	Grain sold	Grain kept	Other uses	Price SL/kg	
							Seed	Feed
		----------%----------						
Arta	204.1	4.5	5.7	66.1	14.9	8.8	8.2 (0.65)	7.5 (0.64)
Rihane-03	437.7	4.5	7.3	71.5	9.1	7.6	8.5 (1.10)	7.7 (0.84)
Zanbaka	26.9	12.7	31.2	48.2	5.1	2.7	7.0 (0.41)	7.14 (0.42)
Tadmor	159.2	0.3	23.9	44.4	21.5	9.9	8.0 (0.00)	7.5 (0.62)
WI2291	30.2	5.0	7.9	73.1	13.3	0.7	7.6 (0.38)	7.2 (0.51)
Total	858.2	3.4	9.6	66.1	13.0	7.9		

The number between parentheses indicate standard deviation.

At harvest time small farmers tend to sell their barley production in one large sale to cover expenses and debt. The larger-scale farmers can wait for a few months, when the price of grain will usually be higher during planting time and supply is low. The average barley price over the study period was 7000-7500 SL/t (120-130 US$/t) at harvest and 8500-10 000 SL/t (170-200 US$/t) at planting time. Some farmers were convinced of the higher performance of certain new barley varieties, but often sold all their barley grain without saving seed, since they were not growing barley in the following season, due to rotation requirements or for fear of storage damage by rats and insects.

At 20 t/y, ‘Rihane-03’ had the most rapid diffusion of the new varieties when sold as seed for new farmers, followed by ‘Arta’ with 9t/y. ‘WI2291’ seed was sold to new farmers only in the first and second years at < 2 t/y. ‘Zanbaka’ was sold to new farmers only in the first, fourth and fifth years at over 3 t/y.

5. Diffusion of new barley varieties

The farmers who received seed of new varieties in the first year came from 24 villages (Table 10). They were not evenly distributed, as only those willing to try the new varieties obtained seed from ICARDA, and most were in Zone 2. The number of villages with new

barley varieties increased to 60 during the study, an average increase of nine per year. The diffusion of new varieties was higher in Zone 2, with six new villages per year, mainly due to stability of barley production in this zone. However, the farmer-to-farmer distribution of new barley varieties is essentially clustered around the initial villages, in Aleppo, Idleb, Hama, Raqqa, and Hasakeh provinces (Figure 3).

Table 10. Changes in numbers of villages growing new barley varieties across stability zones and years

Years	Zone 1	Zone 2	Zone 3	Total
1994/95	1	17	6	24
1995/96	4	23	8	35
1996/97	4	32	14	50
1997/98	4	37	15	56
1998/99	4	41	15	60

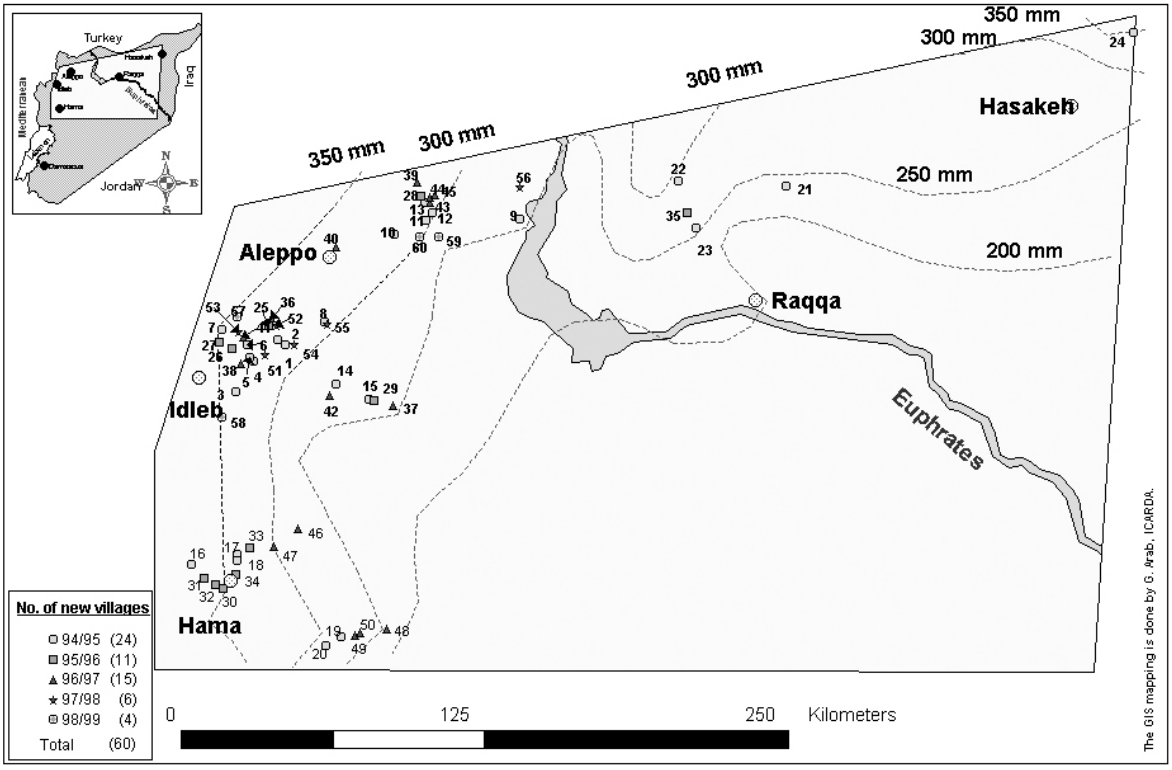

Figure 3. Location of the villages exposed to new varieties of barley during the five-year study.

The number of farmers who received new barley varieties increased from 52 to 206 after four years, an increment of 41% per annum; however, those who adopted new varieties did not follow the same trend as those who merely acquired seed. An adopter was defined as a farmer who, after planting and evaluating a new variety, cultivated it for at least one more season; this avoided treating single-time growers as adopters. Farmers often observe new varieties in rigorous on-farm testing before a decision to adopt or not. In the survey some farmers who tested new varieties did not grow them again. About 30% of growers in 1994/95 grew more than one new barley variety, and some grew up to 4 varieties; this declined to 4% in 1998/99. This indicates that farmers test new varieties and decide on the best varieties for their environments, they may also keep multiple varieties or mixtures within one field, to reduce losses in bad years. The adoption rate (% of farmers who grew a new variety more than once) reached 51%, thus increasing at 12.5% per annum.

The farmers grew new barley varieties on a total of 2388 ha during the study, and diffusion differed between agro-ecological zones (Table 11). The diffusion rate of new barley varieties through farmer-to-farmer seed exchange is depicted in Figure 4.

Table 11. Proportion of cultivated barley area with new varieties by agro-ecological zones

Varieties	Zone 1	Zone 2	Zone 3	Total %	Total area (ha)
Arta	0.0	14.7	2.8	17.5	417.6
Rihane-03	4.5	32.6	0.5	37.5	895.3
Zanbaka	0.0	0.9	5.3	6.2	148.0
Tadmor	0.0	13.2	17.9	31.2	743.8
WI2291	0.0	0.0	7.7	7.7	183.0
Total (%)	4.5	61.4	34.1	100.0	
Total (ha)	107.1	1465.6	815.0		2387.7

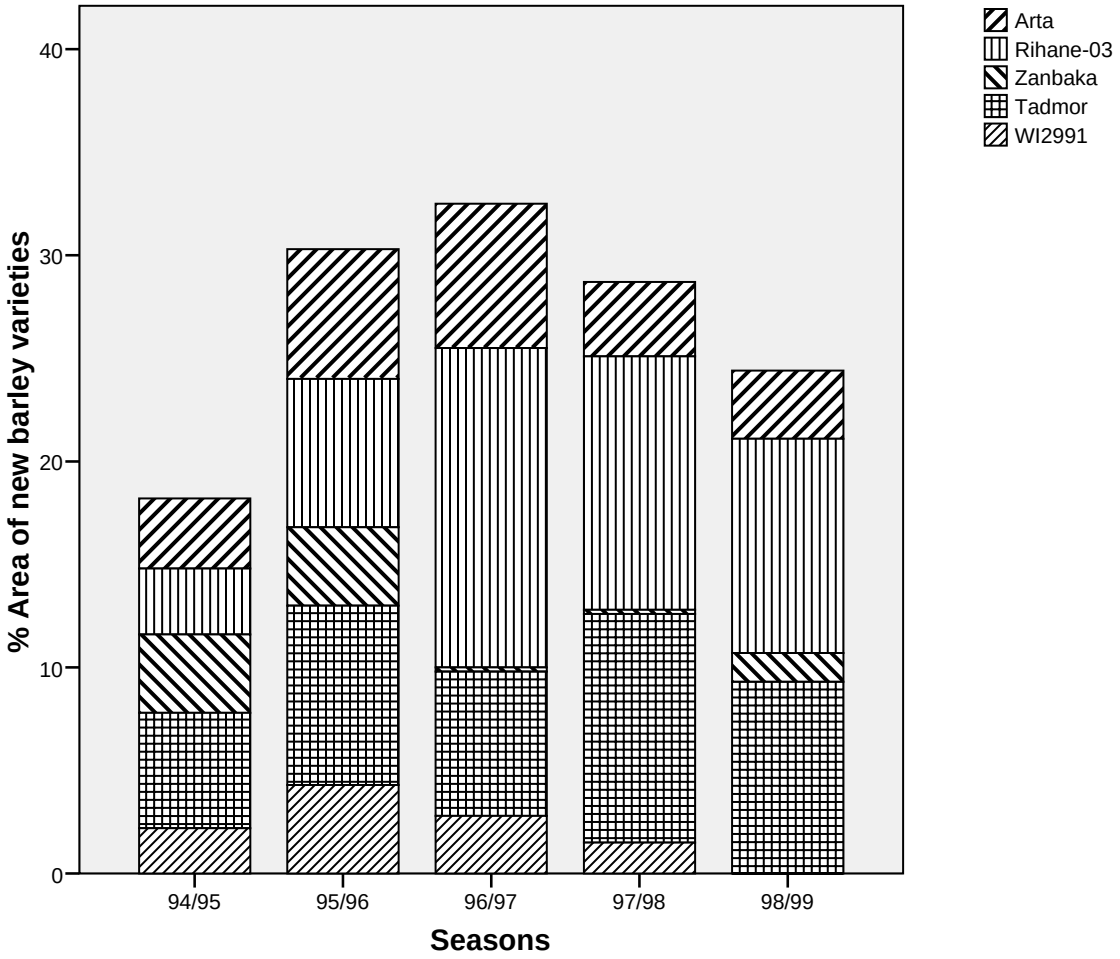

Figure 4. The diffusion of new barley varieties through farmer-to-farmer seed exchange over the five-year study

Only ‘Rihane-03’ and ‘Tadmor’ reached adoption levels of > 10% of the barley area in the studied farms (Figure 4). ‘Rihane-03’ maintained > 10% in the last year, while ‘Tadmor’ was slightly below 10%. This success of ‘Rihane-03’ could be that it is grown in a more favorable zone (Zone 1) and the wetter areas in Zone 2. Some farmers grew it with supplemental irrigation (15 cases during the study) because it is more resistant to lodging than local and other new lines. The other three new barley varieties had adoption levels < 5%. Zanbaka and ‘WI2291’ were not adopted in all years and more effort is needed to persuade farmers to grow these varieties.

'Arta' was mostly grown in moderate environments (Zone 2), 'Rihane-03' in wetter environments (Zones 1 and 2), 'Zanbaka' and 'Tadmor' were grown in drier areas (Zones 2 and 3), and 'WI2291' only in drier environments (Zone 3; Table 11). The number of farmers who grew 'Arta' and 'Rihane-03' increased or remained stable during the study, but the cultivation of the other three varieties declined (Table 12).

Table 12. Frequency of new barley varieties grown by farmers

.	Years					
	1994/95	1995/96	1996/97	1997/98	1998/99	Total
Arta	20	29	36	22	21	128
Rihane-03	17	34	57	58	41	207
Zanbaka	16	7	2	1	3	29
Tadmor	12	6	6	8	7	39
WI2291	8	17	15	9	0	49
Total	73	93	116	98	72	452
Average number of new varieties per farmer	1.40	1.11	1.05	1.04	1.06	1.11
Farmers with more than one variety (%)	29	11	7	4	4	

Diffusion of new varieties between farmers is summarized in Table 13. The adoption rate of new varieties reached 51% in the fifth year, for all varieties across all zones. However, not all harvested seed was planted in the next year, an average of only about 11% was used as seed, and the remainder was used as animal feed.

Table 13. Diffusion of new barley seed varieties among farmers (1)

	Years					
Agro-ecological zones	1994/95	1995/96	1996/97	1997/98	1998/99	Total
Zone 1	1	12	25	28	28	94
Zone 2	37	58	86	115	134	430
Zone 3	14	27	38	43	44	166
Total	52	97	149	186	206	690
Total number of growers	52	84	110	94	68	408
- Adopters (2)	-	39	58	59	48	204

- New growers	52	45	52	35	20	204
Annual adoption rate (3)	-	0.75	0.69	0.54	0.51	

1- Not all farmers interviewed that year grew barley, some may not have cultivated barley due to rotation and other factors.
2- Adopters are defined as farmers who grew new varieties more than 1 time
3- Adoption rate is calculated as number of adopters dived by the total number of new variety growers in the previous year.

6. Analysis of farmer adoption of new barley varieties

To investigate the influences on adoption of new barley varieties, four sets of factors were identified; agro-ecological conditions, farmer perceptions, farming system and farm resources, and farmer characteristics.

Some farmers who adopted new barley varieties also grew local varieties, for the analysis they were divided into four groups, those who: (1) stopped growing barley; (2) grew new barley varieties only; (3) grew mixed barley varieties (new and local); and (4) did not accept (i.e. rejected) the new barley varieties.

6.1 Agro-ecological factors

Agro-ecological factors, such as incidence of droughts and frosts, seasonal temperatures, and soil type affect the performance and adaptation of new varieties and thus adoption by farmers. For example, in the drier areas drought resistance and early maturity may be important characteristics influencing adoption. Similarly, frost incidence, during the growing season, dictate early planting or use of early maturing varieties. In low rainfall areas, Syrian farmers tend to grow black-seeded varieties that are well adapted, but in wetter areas white-seeded varieties are grown. Farmers with sheep, usually in Zones 2 and 3, tend to grow varieties with good feed quality of grain and straw (i.e. two-row varieties), while those in wetter areas tend to grow high yielding six-row varieties. Crop yields are important indicators that farmers use to assess varieties in different environments, and were recorded for the new barley varieties for all farmers in the present study (Table 14). Average yields in 1996/97 and 1998/99 were less than other years. There was a severe frost at the tillering stage in 1996/97, which particularly damaged the new varieties. ‘Rihane-03’ was the most

frost-sensitive of the new varieties, and some farmers were forced to graze it out, or to plow their fields and grow spring chickpeas. This reduced the area planted with 'Rihane-03' in the following year due to a seed shortage. In 1998/99 the grain yields were reduced by drought. Over all seasons, average grain yield in Zone 1 was 2.9 t/ha, yields were lower in the dry areas mainly due to lower precipitation and other factors, including low fertilizer rate, previous crop, and seed rate. The grain yields of new barley varieties were much higher than the local varieties in all the seasons and stability zones. Over the entire study the grain yields of the new varieties, relative to the local varieties, were highest in the drier zones (Table 14); 160% greater than the local variety in Zone 2, 140% greater in Zone 3, and 53% greater in the wetter Zone 1.

Table 14. Rainfed grain yields (t/ha) obtained by farmers for new barley varieties

	Years					Mean across
Variety	1994/95	1995/96	1996/97	1997/98	1998/99	years
	Zone 1					
Rihane-03	4.8	3.1	1.5	3.0	1.9	2.9
	(-)	(0.8)	(0.6)	(0.6)	(0)	(1.0)
Local	2.1	2.2	1.6	2.1	1.3	1.9
	Zone 2					
Arta	3.2	3.2	2.6	3.4	2.3	2.9
	(1.0)	(1.2)	(1.4)	(1.2)	(1.1)	(1.3)
Rihane-03	2.8	3.6	2.0	3.1	1.8	2.7
	(1.2)	(1.4)	(1.5)	(1.1)	(1.0)	(1.4)
Zanbaka	1.7	1.4	-	-	-	1.6
	(0.8)	(0.1)				(0.7)
Tadmor	1.6	2.4	1.9	0.7	1.2	1.6
	(0.6)	(0.8)	(0.1)	(0.1)	(-)	(0.7)
Local	1.3	1.4	0.8	1.1	0.6	1.0
	Zone 3					
Arta	-	-	2.0	1.5	1.0	1.5
			(0.3)	(0.2)	(0.6)	(0.6)
Rihane-03	-	-	1.1	0.7	1.1	1.0

			(-)	(-)	(-)	(0.2)
Zanbaka	1.1	1.7	1.2	1.5	0.6	1.2
	(0.1)	(0.7)	(0.7)	(-)	(0.2)	(0.6)
Tadmor	0.9	2.5	1.6	1.0	0.7	1.3
	(1.0)	(0.6)	(0.5)	(0.4)	(0.4)	(0.8)
WI2291	1.1	1.5	1.2	0.8	-	1.2
	(0.5)	(0.7)	(0.5)	(0.1)		(0.6)
Local	0.6	0.9	0.6	0.4	0.1	0.5

Table 15 summarizes the distribution of farmers in the last year of the study by adoption categories and agro-ecological zones. In drier environments, less farmers adopted new barley varieties. When farmers in wetter areas adopted new varieties, they stopped growing local varieties, while in drier areas most farmers continued growing new and local varieties. All those farmers in Zone 1 who cultivated barley, only 5% of the sample, fully replaced local barley with new varieties (Table 15). Similarly, 45% of farmers fully replaced local with new varieties in Zone 2, higher than in Zone 3 (6%). The reverse was true for those who cultivated only local varieties: 34% in Zone 2 and 73% in Zone 3. 'Rihane-03', the white-seeded six-row variety, was the most frequently adopted variety in wetter environments due to high grain yield and lodging resistance. 'Arta', the white-seeded two-row variety, was mostly adopted in medium environments due to high grain yield and good feed quality of grain and straw. 'Tadmor', the black-seeded two-row variety, was grown in drier environments.

Table 15. Percentage of farmers growing local, new and mixed varieties by agro-ecological zone in 1998/99

	Zone 1	Zone 2	Zone 3	Total
Only new	100	45	6	38
Only local	-	34	73	42
Mixed (local + new)	-	21	21	20
Total	100	100	100	100
N	6	94	33	133

6.2 Farmer perceptions

Normally, farmers do not immediately adopt a new technology or innovation. The time from initial knowledge to final acceptance may range from a few days to many years (Lionberger 1960). In rainfed farming, there are additional considerations such as weather uncertainty or variation in soil quality. Therefore, farmer decisions regarding technology adoption in rainfed farming may be more complex, and take longer than in more favorable environments (Demir 1976; Perrin and Winkelmann 1976; Mazid 1994). Farmer perceptions of technology characteristics are important factors in adoption (Adesina and Zinnach 1993; Mazid 1994); this can be critical in developing countries where there are often wide differences in perception between farmers and agricultural scientists (Adams 1982). These farmer perceptions reflect their experience with the new technology and it should not be automatically assumed that the characteristics of new technology are satisfactory in the opinion of farmers. Farm and farmer characteristics, and their perceptions of technology-specific characteristics, all influence adoption decisions related to improved varieties (Sall et al. 2000). Thus developing varieties that consider farmer perceptions within participatory breeding and selection processes should have better adoption than varieties produced by conventional methods.

In the present study, farmers ranked new barley varieties that they had cultivated, in relation to local varieties (Table 16). There was significant difference between zones in the rank of top variety ($P < 0.001$). About 78% of farmers, who grew ‘Arta’ in Zones 2 and 3, ranked it as the best variety. ‘Rihane-03’ was ranked by 74% as the best variety; however, there was significant variation between zones, 96% in Zone 1 ranked ‘Rihane-03’ as the best variety, 66% in Zone 2, and 25% in Zone 3 (Table 16). The differences across zones show the suitability of ‘Rihane-03’ to wetter environments. About 35% of farmers who grew ‘Zanbaka’ ranked it as the best, the proportion was higher in Zone 3 (41%) than in Zone 2 (25%), confirming that ‘Zanbaka’ is suited to drier environments. ‘Tadmor’ was rated by 58% as the top variety, and 44% chose ‘WI2291’ as the best.

Farmer rankings were influenced by seasonal conditions. Farmers heavily weighted the performance of the variety in the last season they cultivated it, and this affected their planting decisions in the next season.

Table 16. The percent and total number of farmers that ranked new barley varieties better compared to local varieties by zone

The top variety	Zones[1]			All zones
	1	2	3	
	Percent farmers ranking new varieties better than local			
Arta	NA	78	78	78
Rihane-03	96	68	25	74
Zanbaka	NA	25	41	35
Tadmor	NA	64	50	58
WI2291	NA	NA	43	43
No. of observations	46	301	94	441

1- Cells marked NA Table indicate that no growers have cultivated and evaluated the variety in that zone.

Farmers identified their reasons for either continuing cultivation of new barley varieties, or the reasons for non-adoption. The positive characteristics for each variety in the three zones were identified by farmers (Table 17). For continuing cultivation of ‘Arta’, yield was most important, followed by good grain size, and good feed quality of grain and straw. Higher grain yield and lodging resistance were reasons for adoption of ‘Rihane-03’ in Zones 1 and 2. Farmers adopted ‘Tadmor’ because of better grain yield, drought resistance, black seed, and good grain size. For ‘Zanbaka’, plant height and drought resistance were most important, especially in Zone 3. Farmers who adopted ‘WI2291’ rated plant height, good grain yield, lodging resistance, and drought resistance as the most important factors.

Table 17. : Farmers' reasons for adopting new barley varieties **across stability zones for the five-year study (% of total farmers)**

Reasons	Arta		Rihane-03			Zanbaka		Tadmor		WI2291
	Z2	Z3	Z1	Z2	Z3	Z2	Z3	Z2	Z3	Z3
Better yield than local variety	66	67	75	54	25	8	18	47	50	29
Early maturing	1	-	-	-	-	-	12	7	-	4
Cold resistance	3	-	-	-	-	-	-	-	-	-
Good grain size	24	11	2	19	-	8	12	27	29	-
Good feed quality	26	11	-	5	-	-	-	20	-	-
Lodging resistance	7	22	75	53	25	-	-	7	-	18
Good tillering	8	11	-	1	25	-	-	-	13	-
Seed purity	12	-	2	1		17	12	20	13	-
Good plant height	2	-	-	14	50	25	35	-	13	33
Drought resistance	3	11	-	-	-	-	29	-	42	14
Black seed	-	-	-	-	-	-	12	33	38	-
Disease resistance	2	-	-	1	-	-	-	-	-	-
Grain shattering resistance	1	22	-	1	-	-	-	-	-	-
White seed	12	-	-	1	-	-	-	-	-	-
Good tall heads	4	-	-	-	-	-	-	-	-	-
No. of observations	119	9	48	155	4	12	17	15	24	49

The most common reason for non-adoption was a lack of confidence of good performance under local conditions, particularly with susceptibility to frost, disease, and lodging. Not all farmers who grew new varieties continued use in following years; 35% stopped growing barley altogether and replaced it with fruit trees in stony and shallow soils – this occurred in Zone 1 and less in Zone 2. Here farmers believed the trees were more profitable, and agricultural policy encouraged fruit trees, especially olives. Others stopped growing barley because they obtained access to additional water sources and changed to irrigated crops, some farmers changed to other rainfed crops such as wheat and cumin.

Farmer perceptions of new barley varieties and adoption behavior are summarized in Table 18. Chi-square test showed a significant association between perception of new barley varieties and adoption.

Table 18. Farmer attitudes to new varieties and their adoption behavior

Groups	Farmers' attitude			Total
	No difference between local and new varieties	New varieties are better	Local varieties are better	
Stop growing barley	-	50	50	100
Grow new varieties only	2	85	14	100
Growers of local varieties only	-	17	83	100
Growers of mixed (new & local)	2	54	44	100
Total	2	74	25	100

6.3 Farming systems and farm resources

Many variables that describe the farming systems and farm resources could influence adoption of new varieties. Such differences between adopters and non-adopters were analyzed using descriptive statistics. Farm size differences were significant ($P<0.001$): average farm size was 25 ha for those growing only new varieties and 13 ha for those growing only local varieties. There was no correlation between adoption and livestock ownership ($r = 0.08$, non-significant) and land tenure type did not differ between farmer types. The source of family income did not have a significant influence on adoption of new varieties.

In general, local barley is rainfed because it is very sensitive to high rainfall, but 'Rihane-03' has a strong and thick stem which resists lodging under irrigation. Consequently, some farmers in the El-Bab area (Zone 2) grew it for sheep grazing in spring and not for grain, they used a high sowing rate (up to 300 kg/ha) and added more nitrogen fertilizer.

6.4 Farmer characteristics

Characteristics of farmers can be used as explanatory variables in understanding adoption patterns, including factors such as farmer age, education, and family size. Analysis of such factors provides feedback for refining the technology that is appropriate for all farmers, or for farmers with certain resources or skills, and what could make the technology widely available to all farmers.

Farmer age was not a significant factor in the adoption of the new barley varieties. The average age of farmers who exclusively used new varieties (53 years) was not different from that of all farmers in the study (51 years). Family size may affect adoption, especially if a new technology needs more labor. This factor was not significant in adoption behavior, since the new varieties did not require additional labor. There was no significant difference in the education levels between adopters and non-adopters.

7. Multivariate analyses

7.1 Logit model

A Logit model is a type of multivariate analysis, used when the dependent variable is a categorical type, taking one of two mutually exclusive values, such as "adopt" or "not adopt" (i.e. the adoption decision). Logit and Probit models[6] are similar models and were used to predict the probability of adoption, based on farm and farmer characteristics.

In the present study we used a Logit model, with four major sets of factors hypothesized as key issues for adoption behavior. These were zone factor, farm resources and farming system, farmer characteristics, and farmer perceptions. Each main factor was represented by a number of variables. The four major sets of factors described above can be represented by the following variables: farm location by stability zone, family income from off-farm activity, rented farm land, livestock number, tractor ownership, education level, barley area in the farm, total farm size and irrigated area in the farm.

The Logit model was used to identify the most important factors influencing adoption. These factors should represent a few key relationships describing the adoption process, and make future extension and research more efficient (CIMMYT 1993). For this reason, the Logit model included only those variables with significant influence on adoption behavior of farmers. Both backward and forward stepwise procedures were used to identify variables, summarized along with significance values and goodness of fit, in Table 19. Only two variables were key factors

[6] The main difference between the two models is that Logit assumes that the dependent variable follows a logistic distribution, while the Probit model assumes a cumulative normal distribution. Interpretation of the same data will differ only for individuals having extremely high or low probabilities, i.e. in the tails of the distribution (CIMMYT 1993).

that positively influenced farmer adoption decisions: 'total farm size', and 'farmer's perception of new varieties'.

Table 19. Estimated Logit model, including the variables that most influence adoption behavior of farmers

Variables in the Equation	Coefficients	
	B	S.E.
Constant	-.148	.161
Total farm size	.007	.006
Farmer's perception on new varieties 1=positive 0=Otherwise	5.676	1.011
Cases correctly classified	79.2%	
-2 Log likelihood	332.03	
Cox & Snell R Square	0.355	
Nagelkerke R Square	0.541	

7.2 Multiple regression analysis

Farmer adoption of new varieties occurs in two stages. Firstly, after making their assessment, they decide whether to adopt a new variety or not. Secondly, if adoption is chosen, they decide the area for cultivation of the variety. These adoption decisions can be investigated using multivariate analysis. The determining factors of adoption of new barley varieties were investigated using multiple regression analysis, and to identify the important variables affecting the proportion of farm barley area planted to new varieties.

As for the Logit model (see 7.1), four major sets of factors were hypothesized as influencing adoption behavior: agro-ecological factor, farm resources and farming system, farmers' characteristics, and farmers' perceptions. Each major factor was represented by a number of variables. Using the descriptive analysis, these four main factors can be represented by the following variables: farm location by agro-ecological zones, family income from off-farm activity, rented area, livestock number, tractor ownership, education level, barley area in the farm, total farm size, irrigated area in the farm, and farmer's perception of new barley varieties (Table 20)

Table 20. Means of variables included in regression analysis by agro-ecological zones

Variable	ZONE			Average
	1	2	3	
Proportion of new varieties area to total barley area (%)	100.0	63.4	37.7	59.6***
Family income from off-farm (%)	37.0	32.2	49.6	37.4***
Tractor owned (1 = yes, 0 = no)	0.3	0.5	0.1	0.4***
Number of sheep owned (head)	0.0	19.6	5.7	14.1***
Education (High school and above; 1 = yes, 0 = no)	0.5	0.5	0.6	0.5
Total farm size (ha)	20.4	26.1	19.1	23.7
Proportion of irrigated farm area (%)	68.4	23.1	13.8	24.5***
Farmer perception on new varieties (1 = positive, 0 = no)	0.9	0.6	0.3	0.6***
Farm location (Zone 2 = 1, 0 = no)	0.0	1.0	0.0	0.6***
Farm location (Zone 3 = 1, 0 = no)	0.0	0.0	1.0	0.3***
N	45	329	141	515

*** Significant differences between zones ($P < 0.001$).

Backward and stepwise analyses of Ordinary Least Square of multiple linear regression were used to identify the important factors affecting area of new varieties; factors were percentage of family income from off-farm, livestock number, tractor ownership, education, farm location by agro-ecological zones, total farm size, irrigated area in the farm, and farmer perception on new varieties. The multiple linear regression had an adjusted R^2 of 0.504 (Table 21).

Table 21. Ordinary Least Square regression estimates of the effects of farm resources and socioeconomic characteristics on area of new barley varieties

Variable	Coefficients [a]		*t*	*P*
	B	Std. Error		
(Constant)	35.947	6.431	5.590	0.000
Family income from off-farm (%)	0.230	0.044	5.289	0.000
Tractor owned (1 = yes, 0 = no)	1.944	3.444	0.564	0.573
Number of sheep owned (head)	-0.140	0.060	-2.349	0.019
Education (High school and above; 1 = yes, 0 = no)	1.940	3.000	0.647	0.518
Total farm size (ha)	-0.058	0.036	-1.600	0.110

Proportion of irrigated farm area (%)	0.115	0.047	2.433	0.015
Farmer perception on new varieties (1 = positive, 0 = otherwise)	50.736	3.116	16.281	0.000
Farm location (Zone 2 = 1, 0 = no)	-11.225	5.589	-2.008	0.045
Farm location (Zone 3 = 1, 0 = no)	-26.953	6.154	-4.380	0.000

a. **Dependent Variable**: Percentage area of new varieties, F (9, 505) = 59.008, $P < 0.001$. Adjusted $R^2 = 0.504$.

8. Conclusion

In the present study we used a stringent definition of adoption rate; adopters were those who had prior knowledge of the variety rather than all growers of the varieties. The factors influencing adoption behavior of farmers for new barley varieties were identified and investigated.

Farmer-to-farmer seed exchange was important in diffusion of new barley varieties. There were relatively high adoption rates of new varieties (about 50% in the fifth year) among farmers who received these varieties from farmers, and farmers' decisions to continue growing new barley varieties were based on their evaluation of their performance. The second most important source of new varieties, after seed saved from a previous harvest, was purchase from neighbors, indicating existence of local commercial systems of seed distribution. This suggests ways to strengthen seed supply systems for crops like barley, where state and private seed companies have not been successful in supplying seed. Community-level seed technology is necessary to guarantee seed quality and establish trusted local seed experts to maintain flow of new germplasm into communities. Such experts could be focal partners of participatory germplasm improvement programs. The results of the present study show that many farmers did not continue growing some varieties after their initial evaluation, particularly in the drier zones, indicating that their participation in the breeding process maybe the way to go. The results also show that farmers perceptions of the new varieties played significant role in their adoption. This suggests that farmer participation in varietal development and evaluation and understanding of their criteria for barley varieties can increase adoption. The farmer-to-farmer seed distribution which was demonstrated in this study indicates the existence of underutilized local mechanisms that

can complement formal seed systems and that can form the basis for community seed enterprise development.

Greater support to the informal seed sector should be focused on: communication, information, and markets; improving farmers' skills in seed production through extension and training; and increasing the role of agricultural extension agents in developing an informal seed system.

References

1) Adams, M.E.1982. Agricultural extension in developing countries. Longman, London, U.K.
2) Adesina, A.A. and Zinnah, M.M. 1993. Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. Agricultural Economics, Vol. **9** (1993): 297-311. Elsevier Science Publishers B.V., Amsterdam.
3) Almekinders C. J. M., G. Thiele and D.L. Danial. 2007. Can cultivars from participatory plant breeding improve seed provision to small-scale farmers? *Euphytica* 153: 363–372
4) Ceccarelli, S. and Grando S. 2007. Participatory plant breeding in water-limited environments. *Experimental Agriculture* (in press).
5) Cromwell, E. (ed). 1990. Seed diffusion mechanisms in small farmer communities: Lessons from Asia, Africa and Latin America. Agricultural Administration Network. Network Paper 21.
6) Demir, N. (1976) Adoption of new bread wheat technology in selected regions of Turkey. CIMMYT, Mexico City.
7) Di Falco, S. and Chavas, J. P. 2006. Crop genetic diversity, farm productivity and the management of environmental risk in rainfed agriculture. European Review of Agricultural Economics 33: 289–314.

8) FAO .1999. Seed Production and Improvement Assessment for the Near East and North Africa (Seed security for food security) Seed and Plant Genetic Resources Service (AGPS), in Proceedings of the Regional Technical Meeting on Seed Policy and Programs in the Near East and North Africa. Larnaca, Cyprus 27 June - 2 July 1999. http://www.fao.org/AG/aGp/agps/Cyprus/Paper1.htm

9) ICARDA (International Center for Agricultural Research in the Dry Areas). 1989. Sustainable Agriculture for Dry Lands – ICARDA's Strategy. ICARDA, Aleppo, Syria.

10) Lionberger, H.F. 1960. Adoption of new ideas and practices. Ames Iowa State University Press. USA.

11) Mazid, A. 1994. Factors Influencing Adoption of New Agricultural Technology in Dry Areas of Syria. PhD thesis. University of Nottingham, UK.

12) Mazid, A. and Hallajian, M. 1983. Crop-Livestock interaction: Information from barley survey in Syria. ICARDA research report No. 10, ICARDA, Aleppo, Syria.

13) Mona, N. 1986. Structure and responsiveness of barley production in Syria. Ph.D. dissertation, College Station: Texas A&M University, USA.

14) Negatu, W. and A. Parikh. 1999. The Impact of Perception and Other Factors on the Adoption of Agricultural Technology in Moret and Jiru Woreda (district) of Ethiopia. Agricultural Economics 21: 205–216.

15) Perrin, R. and Winkelmann, D. 1976. Impediment to technical progress on small versus large farms. American Journal of Agricultural Economics, 55: 888-894.

16) Radwan, J.E. 1997. The role of the public seed sector in Syria. Pages 89-93 *in* Alternative Strategies for Smallholder Seed Supply: Proceedings of an International Conference on Options for Strengthening National and Regional Seed Systems in Africa and West Asia, 10-14 March 1997, Harare, Zimbabwe.

17) Rogers, E.M. 1983. Diffusion of Innovations. Third edition. Free Press, New York.

18) Sall , S., Normand. D. and Featherstone,, A.M., 2000. Quantitative Assessment of Improved Rice Variety Adoption: The Farmer's Perspective. Agricultural Systems, 66: 129-144.

19) Somel, K. 1987. Food and agriculture in West Asia and North Africa: Projections to 2000. In Farm Research Management Program Annual Report for 1987, ICARDA, Aleppo, Syria.

20) Sperling, L., Scheidegger, U. and Buruchara, R. 1996. Designing seed systems with small farmers: principles derived from bean research in the Great Lakes Region of Africa. Network Paper No. 60. January 1996.

Appendix 1

Questionnaire for Seed Tracer Study

Province_____ Season: _____
Village_____ Interviewing date:_____
Zone_____
Farmer's name_____
Farmer's No._____

1. How did you find out first to grow a new barley variety?

_____

2. Did you have some seeds of particular new varieties to grow in the next season?

If Yes: If no: Discontinued reasons

Variety	Amount (kg)	Source	Price (SL/kg)	When	
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

3. What was the area of barley, seed rate, grain yield, and total grain production in the previous season?

Variety	Area(ha) Planted	Harvested	Grazed	Seed rate (kg/ha)	Yield (kg/ha)	Total production (kg)
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
Local	_____	_____	_____	_____	_____	_____

3a. What was your grain allocation of new varieties at harvest in the previous season?

Variety	Kept for seeds	Sold as seeds	Sold as feeds	Price (SL/kg)	When	Kept as feed	others
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____

3b. Did you sell some grain of your new varieties at harvest time to other farmers for planting in the next season? Yes _____ No _____

Variety	Amount (kg)	Location	Farmer's name	Price SL/kg	When/month	Local Price
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____

_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____

3c.What were the reasons for keeping some seeds for planting in the next season (Positive traits of the varieties)?

Variety	Reasons
_____	_____
_____	_____
_____	_____
_____	_____

3d. What were the reasons for selling some varieties as feeds and not keeping as seeds for next season (Negative traits)?

Variety	Reasons
_____	_____
_____	_____
_____	_____
_____	_____

4. What was the soil type under the various varieties that you have grown (rotation)?

Variety	Soil Type (Deep, Medium, Shallow)
_____	_____
_____	_____
_____	_____
_____	_____

5. What was the previous crop under the various barley varieties?

Variety	Previous crop
_____	_____
_____	_____
_____	_____
_____	_____

5a. Do you think previous crop affected the following barley yield?

_____

6. Did you irrigate one of the new varieties in the previous season?

Yes_____ No_____

Variety	Area (ha)	When/month	Yield (kg/ha)	No. of irrigations
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

7. Did you change the use of fertilizers when using the new varieties?

Normal application for local varieties			**Change in application for new varieties**		
Type	Amount (kg/ha)	week /month	Type	Amount (kg/ha)	Time /month
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

8. Did your sheep graze one of the new varieties at the green stage in the previous season?

Yes_____ No_____

Variety	Area (ha)	week/month	Reason
_____	_____	_____	_____
_____	_____	_____	_____

9. What new varieties are you growing in the next season?

Variety	Amount (kg)	Area (ha)	Source
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
Local	_____	_____	_____

10. Farmer's opinion of new barley varieties compared to local varieties?

Variety	**Ranking order as favorable**	**Reasons**
Arta	_____	_____
Rihane-03	_____	_____
Zanbaka	_____	_____
Tadmor	_____	_____
WI2291	_____	_____
Local	_____	_____

Appendix 2

SEED TRACER STUDY
Agronomic and socioeconomic feedback for farmers who grew new barley varieties

Province _____
Location _____
Zone _____
Farmer's name _____
Farmer's No. _____
Year

1. Age of household head _____ years

2. Education | None | Preliminary | No. of years studying | BSc
_____ | _____ | _____ | _____

3. Family size _____ members
Less than 12 _____ | Above 12 _____ | M _____ | F _____

4. Family income
_____% Crops
_____% Livestock
_____% Off-farm _____
100 **Total**

5. Average farm size (current year) _____ ha | RF. _____ | SI. _____ FI. _____ | Private _____ | Rented _____

6. Total barley area (ha)

	1994/95	1995/96	1996/97	1997/98	1998/99	99/2000
New variety	_____	_____	_____	_____	_____	_____
Local	_____	_____	_____	_____	_____	_____
Total	_____	_____	_____	_____	_____	_____

7. Do you normally purchase barley to feed your sheep?
Grain Yes ____ No _____ Amount (t)_____
Straw Yes ____ No _____ Amount (t)_____

8. Livestock

Kind	No. of heads
sheep	_____
goats	_____
cows	_____

9.Machinery Priv./Shar. Period of ownership

	Tractor	___ / ___	_____
	Seed drill	___ / ___	_____
	Combine	___ / ___	_____
	Pick up	___ / ___	_____
	Well pump	___ / ___	_____
Others		___ / ___	_____

10.Type of house	New (cement)	Old (mud)	No. of rooms
	_____	_____	_____

11.Television & satellite dish _____

12. Telephone _____