ASSESSING MAIZE VARIETAL DETERIORATION USING ON-FARM AND ON-STATION RESEARCH: AZAM MAIZE IN THE SWAT VALLEY, NORTH WEST FRONTIER PROVINCE, PAKISTAN

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SUMMARY

The extent and rate of deterioration of an improved maize variety maintained by smallholders in the irrigated Swat Valley, Northern Pakistan is analysed. The variety Azam had been in farmers' fields for up to 4 years, and had been maintained by farmers using different criteria. Most seed is selected on the cob, and cob size was given high priority amongst the majority of farmers surveyed. Trials were conducted on-farm and on-station in 1989 in the Swat Valley to compare the performance and plant characteristics of the farmer-maintained variety, old Azam, with breeder-maintained new Azam. On-farm trials were conducted in 46 farmer fields with a plot of new Azam grown under farmer practice within a field of old Azam. The on-station trial involved growing 50 versions of the old variety maintained by farmers along with the new variety and local checks. The only response variables to show consistent differences between the new and old Azam were plant height and ear height. Using these characteristics as an indicator, the mean deterioration of the old variety from the more reliable on-station trial was 55%. The mean age of the old variety was 2.5 years. Predictions using the logistic function imply that the old Azam would be more than 95% deteriorated by 4 years of age. The implications of this new information for seed programs for improved varieties of maize are that the rate of deterioration of improved varieties is high, probably more than previously considered. Suggestions are made for further research of this nature, which promises to provide more precise information for smallholder crop development, especially concerning seed industry strategies for open-pollinated varieties.

INTRODUCTION

Open-pollinated maize *(Zea maiz L.)* varieties are the predominant form of maize seed planted in the developing world (CIMMYT 1987). Despite increasing use of hybrids, more than half of the maize area planted in developing countries is to open-pollinated varieties. In 1990, 45% of the developing world's maize area was planted to farmers' own seed, 16% to commercial seed of improved open-pollinated varieties and 39% to hybrids, which are dominated by Argentina, Brazil and China. Open-pollinated maize varieties are likely to prevail in particular maize growing regions for many years, especially where conditions do not encourage the ready expansion of hybrid maize (CIMMYT 1987).

An important question in the provision of open-pollinated maize seed is the appropriate rate of turnover of improved commercial seed by the farmer. Typically, farmers who plant improved open-pollinated maize varieties from commercial seed use the resulting crop to select seed which is re-cycled over a number of seasons. This saves on seed costs, before replacement commercial seed must be purchased. Over time, however, the selected seed deteriorates for reasons examined in more detail in this paper. The extent of deterioration is critical in determining the optimal turnover of commercial seed if adopted by farmers, although the price of seed, planting rate and differences in productivity between commercial seed and farmer-maintained seed are also major factors in this decision (CIMMYT 1987, Heisey and Brennan 1991).

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This paper is concerned with assessing the extent and rate of maize varietal deterioration in a smallholder maize growing region of NWFP, Pakistan. Background to this research is summarised in Byerlee, Khan and Saleem (1991). They conducted a series of on-farm research studies of maize in the irrigated Swat Valley from 1984 to 1988. Amongst other research, the improved variety Azam (developed by maize breeders at the Cereal Crops Research Institute, Pirsabak, NWFP in collaboration with CIMMYT scientists - see CIMMYT 1989) was introduced to farmers with a series of on-farm trials. These were conducted in three particular locations, one in the hills of Swat and two in the irrigated Swat Valley surrounding the villages of Kabbal and Chalyar, some 10 km W and 25 km NNE of Mingora, respectively. These two locations were returned to in 1989 to conduct the research reported in this paper. The location of the study area is presented in Figure 1, and the concept of measuring maize varietal deterioration is summarised in Figure 2.

PREVIOUS RESEARCH

The processes employed in the harvesting, selection and storage of seed of different crops by smallholder farmers in developing countries vary considerably (Seeley 1988, Cromwell 1990, Heisey 1990, Bellon and Brush 1993). Nevertheless, there is a dearth of research on seed under smallholder farming conditions. Very detailed studies of cropping systems, including diagnostic farming systems research, often totally neglect the seed question, despite its importance (Douglas 1980, Borlaug 1981, Wedderburn and Chatha 1982).

The earliest testing of differences across farmers of the performance of open-pollinated improved maize varieties is reported by Mosher (1962). The trials were undertaken by Perry G. Holden in Sioux County, Iowa and involved 75,000 field plots using County Demonstrations from 1904 to 1915. Open-pollinated maize seed from different farmers in the County was collected and tested under uniform conditions. Surprisingly large differences in yield were observed (the mean yield across 5,245 farmers from 10 years of trials was 3.5 t ha^{-1}, with the top 10% averaging 4.1 t ha^{-1} and the lowest 10%, 2.6 t ha^{-1}). Holden then compared "seed house seed" with farmer varieties: essentially the same trial as reported in this article. Interestingly, the performance of the farmer seed was above that of the seed houses of the time!

A multitude of trials concerning maize seed and breeding since then has been undertaken (Sprague 1977, Jugenheimer 1985). However, no trials are reported on how open-pollinated varieties maintained on smallholder farms change over time genetically or in terms of performance and phenotype.[2]

On-farm research by Seeley (1988) involved a detailed investigation of seed selection, maintenance and exchange between farmers up to 40 km NW of Pokhara, Nepal. She reported the problem of contamination of seed and refers to feedback from farmers highlighting change over time in performance of improved varieties, maintained on farm. Similar issues are referred to in Mexico (Bellon and Brush 1993), Ghana (Ghana Grains Development Project 1991) and Pakistan (Byerlee, Khan and Saleem 1991).

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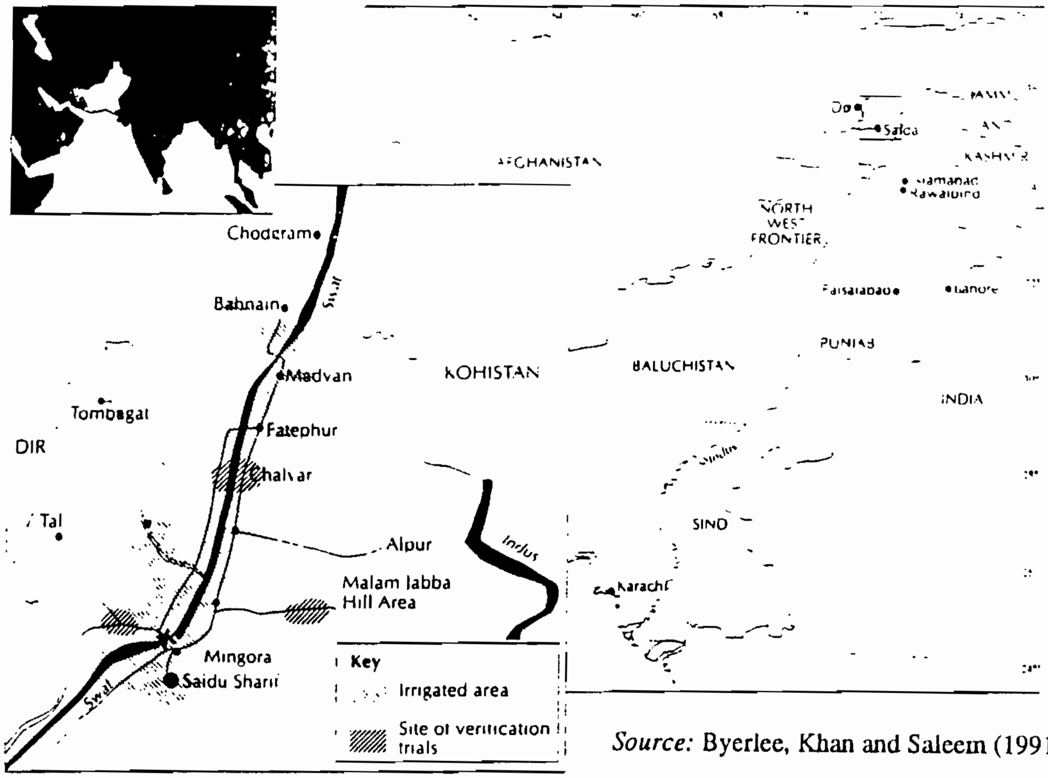
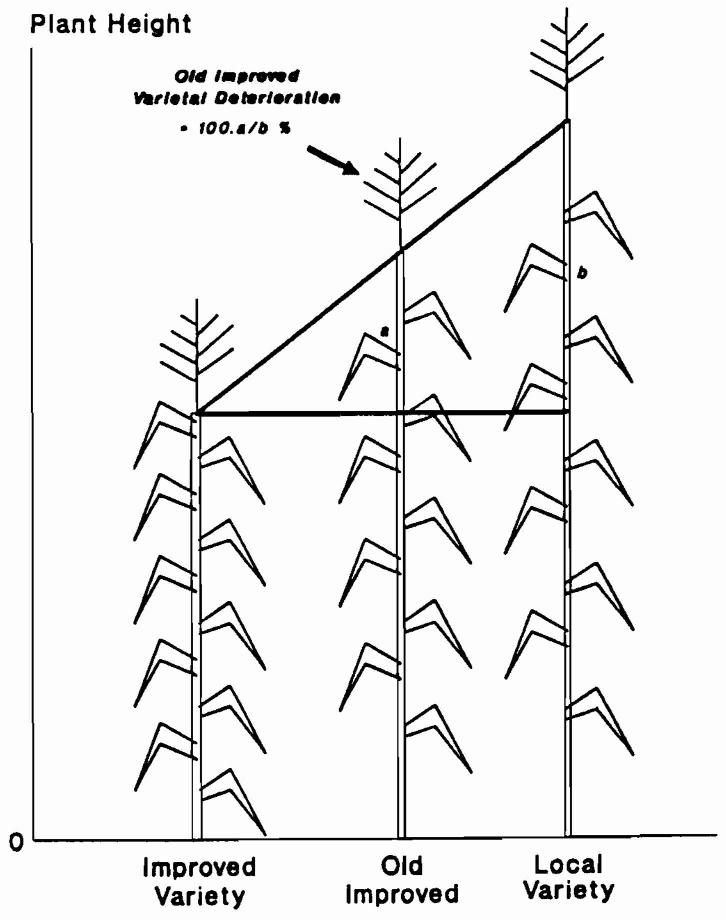
[2] Using the Agricola CD-ROM database from 1970 to 1993, nearly 60,000 research articles and reports on "maize" (or "corn") are in the catalogue. On "maize seed" (or "corn ..."), there are about 500, many from Eastern Europe and the former Soviet Union. Not one article on maize varietal deterioration was found.

Fig. 1 Map of the Research Location



Source: Byerlee, Khan and Saleem (1991)

Fig. 2 Measuring Varietal Deterioration with the Example of Plant Height



ISSUES CONCERNING MAIZE VARIETAL DETERIORATION IN SMALLHOLDER AGRICULTURE

Overview

The nature of smallholder maize production implies there are strong reasons why farmer-maintained varieties deteriorate over time.[3] The principal sources of deterioration are (1) pollen contamination from neighboring fields in which other varieties or local varieties are grown (2) particular seed selection practices employed on the farm, which lead to varietal deterioration (3) mixing of seed in the harvesting, drying, shelling and seed storage processes and (4) regrowth from previous maize crops or other rogue plants contaminating the improved variety.

Contamination

The extent to which pollen moves across maize fields has been well documented (Sprague 1977, Jugenheimer 1985). Airy (1950) shows that a low but significant percentage of pollen can contaminate maize up to 175 m from the pollen source, although greater than 1% of contamination in fields occurred within 10 m approximately of the source (for maize with tassels). Hutchcroft (1959) has shown that the percentage of contamination can grow very rapidly as the number of undetasseled plants in a hybrid seed field increases. The extent of contamination and its direction will depend upon the timing of inflorescence and winds during this time. Open-pollinated varieties, as compared to F_1 hybrids for example, have a longer time period for inflorescence overall because of greater genetic diversity within a crop. As the duration of inflorescence increases, so does the probability of contamination: because the chances of stronger pollen-carrying winds increase with time.

All commercial maize seed is meant to be grown with strict isolation requirements. Typically, minimum numbers of isolation (border male) rows and distances from other maize fields set the field requirements in growing certified maize seed. A minimum distance of 200 m for certified open-pollinated maize seed, without isolation rows, is recommended (Jugenheimer 1985, CIMMYT 1984). The minimum is more variable in hybrids, with the number of border rows being negatively related to the distance from other maize fields and the size of the seed field. For certified seed fields less than 8 ha, a minimum of 16 isolation rows is recommended and a minimum distance of 25 m from neighboring maize.

The size of many fields in smallholder maize areas in developing countries is such that the criteria for certified seed production could not be met economically. For example, the average size of maize fields in the study area was less than 0.2 ha. A 2x1 rectangular field of 0.2 ha implies that the longitudinal centre line of the field will be no further than 16 m from a neighboring one (equivalent to 20 border rows at 80 cm spacing). From casual observation, most fields in the study area were thinner than a 2x1 rectangle, although much more irregular in shape. This implies that considerable contamination across fields will occur, unless all farmers grow the same variety simultaneously.

Farmers' Seed Selection Methods

Own-grown seed on smallholder maize farms is typically selected at one of three stages: in the field, on the cob or from the shelled grain. Each of these methods has different implications for genetic change in an open-pollinated improved variety maintained by farmers.

Selection in the field involves the farmer selecting ears prior to or during harvest on the basis of particular criteria (often plant height, plant size and strength, ear size, ear cover and plant

[3] "Deterioration" in this context means any drift genetically away from the makeup of the commercial improved variety. Sometimes farmers will select a genetic makeup over time which is superior to the commercial variety, in terms of their special needs and circumstances. For more details on seed programs for open-pollinated maize varieties, see CIMMYT (1984).

health). A consequence of selecting for most of these criteria is that the genetic drift in the improved variety will be towards taller and larger plants (generally local varieties are considerably taller then improved ones). This is likely to reduce the harvest index and grain yield of the local variety (Johnson *et al.* 1986). Selection of seed in the field is rare amongst smallholder farmers of Pakistan.

Selection of seed on the cob is common in smallholder maize systems. The various criteria used are not well documented, although large cobs, colour, freedom from disease, hardness, and kernel size and shape are important. Choosing large cobs and large kernels will probably lead to change in the genetic makeup of the variety through time, since these characteristics are associated with plant height and harvest index (Wedderburn 1994).

Selection of seed from shelled grain theoretically will minimise the chances of the selected variety drifting genetically because of particular selection criteria employed on the farm. However, because of contamination and mixing, there is a high chance of the seed selected after shelling not remaining genetically akin to the original commercial variety.

Unintentional Mixing

Another potentially important source of deterioration of maize varieties with smallholders is through unintentional mixing of seed in the harvesting, seed selection and storage processes. Failure to segregate varieties or to clean the drying floors, shelling areas, shellers or seed storages will obviously contribute to mixing.

All maize in the study area is manually harvested, with the ears being separated from the stalks initially and then the stalks being cut and taken to dry. Ears and stalks are harvested at high moisture levels (Byerlee, Khan and Saleem 1991). Ears are dehusked manually and the cobs dried on open earthen drying floors. At this point there is considerable opportunity for maize seed to intermix. Mechanical shelling is the norm in the area and this represents another opportunity for mixing. Finally, the seed is stored in sheds at the home, in solidly constructed wooden bins. Typically one farmer had one seed bin, as traditionally farmers only grew local varieties. More details on farmer practices in the Swat District concerning selection and management of own-grown seed are presented in the following Section.

Rogue Plants

Rogue plants in smallholders' fields of improved variety might also be a potential contaminant, although no evidence is available on this. The intensity of cropping and grazing in most smallholder farming systems probably ensures minimal presence of rogue plants.

MAIZE SEED MANAGEMENT IN THE SWAT VALLEY

Maize is a major crop for farmers in Swat, fulfilling important needs both as a food grain (matching the other main food crop, wheat - *Triticum aestivum*) and a source of green and dry fodder. The value of fodder derived from maize approximates the value of grain produced. This leads to special management of maize as a dual-purpose crop (Byerlee, Khan and Saleem 1991). In particular, farmers plant maize seed at very high levels and thin the crop throughout the growing season. The average seed rate for maize in the Swat Valley during 1983-85 was 96 kg ha^{-1} (Byerlee *et al.* 1987). Contrast this with a typical seed rate for hybrid maize in the USA of under 20 kg ha^{-1}.

Stand density after the first major thinning (termed *seeling*, at about 20-25 days after planting) averaged 144,000 plants ha^{-1} in the farmers' fields in 1989. By 50% silking, the stands had been thinned to 104,000 plants ha^{-1}, on average, and by harvest to 80,000 plants ha^{-1}. This followed the pattern observed previously in farmers' fields, although the final harvest density was sizably above that reported for earlier years (65,000 plants ha^{-1}). The implications for grain and fodder production of such stand management are discussed in detail in Byerlee, Khan and Saleem (1991).

Because of very high seed rates and the lack of an effective seed industry in the region, farmers have traditionally planted open-pollinated varieties of maize (Byerlee and Hussain 1986, Longmire 1989, Longmire and Hussain 1991). For Swat District in 1989, 17% of the maize area was planted to improved varieties. Virtually all seed planted was non-commercial. Details of maize production and varietal and seed use in Swat are presented in Table 1, comparing practices in the irrigated Swat Valley with those in the rainfed mountains. The research location, in contrast to the Swat District overall, had a much higher area planted to the improved variety Azam. In 1988, just over 80% was planted to Azam, some there since 1985.

More details on seed selection methods for farmers in Swat District are presented in Table 2. Similar data were obtained from the farmers included in the sample for this study and details concerning their seed management are summarised in Table 3. Of special interest is the high priority given to selecting large ears or cobs. Most seed is selected from the cob.

METHODS EMPLOYED

On-Farm Research

Farmers were initially approached in the research location (around the villages of Dagai - adjacent to Kabbal - and Chalyar, Swat Valley) in May, 1989, about one month before the expected planting date for maize. Farmers were selected on the criterion that they had been growing the improved variety Azam for at least one crop cycle and would be planting farmer-selected Azam seed in 1989. A target sample size of 50 farms was set, 50 farmers exchanged seed and 46 on-farm trials were recorded.

The first meeting with each farmer involved providing about 4 kg of "new" Azam seed (maintained by Cereal Crops Research Institute - CCRI - and obtained there) in exchange for a small amount (less than 1 kg) of "old" Azam seed that had been maintained by the farmer and was intended for planting by them in 1989. The farmer was asked to grow at least 500 m^2 (1 *kanal* in local terms) of new Azam in one part of their old Azam field and to manage the trial according to own practice and evenly across the whole field. Farmers were asked details about the old Azam seed, the original source and the number of years the variety had been maintained on farm. Farmers were pleased to participate, as they saw the 4 kg of new Azam as a means to replace seed of the improved variety. Generally, they had a preference for Azam over other varieties (Byerlee, Khan and Saleem 1991).

The on-farm trial involved recording crop performance and plant characteristics, for the new Azam and the old Azam separately. Main variables of interest were: (1) grain yield (2) stover yield (3) total dry matter yield (4) plant height (5) ear height (6) days to 50% silking (percentage of barren plants. Yields of stover and grain and moisture content of grain were measured using crop cuts at harvest. No moisture content of stover was obtained and this was assumed to follow the ratio of stover to grain reported for Azam in Byerlee, Khan and Saleem (1991, Table 8.9). Three plots per field totalling 10 m^2 were cut. Individual counts of plant height and ear height from 10 randomly selected plants within the plots were taken and recorded to obtain estimates of the variance of these variables, as well as the mean.

Farms were visited regularly during the growing season, and farmers were interviewed soon after harvest to obtain details on management practices for the Azam field and on Azam seed selection. Data were analysed using the statistical package, SPSS, Statistical Package for the Social Sciences.

Table 1. *Maize Production and Varietal and Seed Use by Environment, Swat District, 1989*

Item	Irrigated Valleys	Rainfed Mountains	Swat District
Total Cultivated Area Per Farm (ha)	2.50	2.00	2.25
Maize Area Per Farm (ha)	1.76	1.36	1.56
Percentage of Area to Improved Maize (%)	23	9	17
Percentage of Area to Azam Variety (%)	16	4	13
Seed Rate Local Varieties (kg ha^{-1})	72	68	70
Seed Rate Improved Varieties (kg ha^{-1})	50	61	52
Percentage of Farmers with Local Variety Only (%)	76	85	81
Percentage of Farmers with Improved Variety Only (%)	18	8	13
Percentage of Farmers with Local and Improved (%)	6	7	6
Overall Cropping Intensity Index	184	168	178
Duration of Maize (days)	106	110	108
Mean Altitude (masl)	910	1365	1110

Source: PARC/CIMMYT Maize Survey of Pakistan 1989, see Asghar and Longmire (1990). Sample size was: Irrigated Valleys, 85 farms; Mountains, 85 farms. Means of variables are presented.

Table 2. *Age of Maize Varieties and Methods of Seed Selection by Environment, Swat District, 1989*

Item	Irrigated Valleys	Rainfed Mountains	Swat District
Age of Local Varieties (yrs)	16.7	14.1	15.5
Age of Improved Varieties (yrs)	3.4	2.1	3.2
Method of Selection of Seed of Local Variety (% of farmers)			
- From Cobs on Plant	10	1	6
- Cobs Before Shelling	73	76	74
- Grain after Shelling	17	23	20
Method of Selection of Improved Maize Seed (% of farmers)			
- From Cobs on Plant	0	0	0
- Cobs Before Shelling	47	100	56
- Grain after Shelling	53	0	44
Original Source of Improved Variety (% of farmers)			
- Research & Extension	70	36	63
- Farmers: Same Village	23	21	23
- Farmers: Other Village	7	43	16

Source: As for Table 1.

Table 3. *Criteria Employed in the Selection of Old Azam Seed by Farmers in Varietal Deterioration Trials, Swat Valley, 1989*

Criterion	Frequency of: Criterion 1	Criterion 2
Large Cob Size[1]	29	8
Full Husk Cover	3	22
Rounded/Undented Grain	5	2
Uniformity	2	0
Compact Cob	1	2
No Lodging	0	1
Grain Softness	0	1
Miscellaneous	6	8

[1] In a few cases, large cob size and tall plant combined.

On-Station Trials

The small amount of old Azam seed obtained from the farmer was used to establish on-station trials on maize research plots at Garshin, Swat Valley. The farmer-maintained seed was also grown in trials at CCRI Station, Pirsabak, although inclement weather and the difference of temperature, rainfall and altitude, as compared to Swat, made results of these not worth analysing.

Layout for the on-station trial involved randomly allocating the 50 lots of old Azam seed to rows of 25 m length and 80 cm width and interspersing these with 5 rows of new Azam from CCRI (rows 8, 20, 30, 40 and 50) and 3 rows of local checks (16, 32 and 48). The local checks were obtained from farmers in the area who had maintained local maize in fields separate from the improved maize. The trial received 112 kg ha^{-1} of N and 28 kg ha^{-1} of P. Three replications of the trial were made and two cuts for yield and other plant characteristics were made for each row from separate 8 m^2 areas within the row. Border rows were planted to minimise border effects. The variables of primary interest were the same as for the on-farm trials and standard procedures were employed to convert measured plot yields to meaningful units. Individual plant height and ear height measures were taken for up to 15 plants in each row, so that the variance as well as mean of these variables could be calculated.

RESULTS

On-Farm Trials

The main results of the on-farm trials are reported in Table 4. The mean grain yield for new Azam was about 700 kg ha^{-1} higher than averaged in the 1985 trial in Byerlee, Khan and Saleem (1991). Grain yield of new Azam averaged 14% higher than that of old Azam. This compares with a 12% difference reported between the new Azam and local maize in Byerlee, Khan and Saleem (1991). It is possible that farmers managed their plot of new Azam slightly differently to their old Azam, in an attempt to obtain more grain per unit area for seed. The final harvest density for new Azam was slightly higher than that for old Azam, and well above the earlier trials, suggesting the farmers were reluctant to thin the plot heavily. The lack of control of farmer practice between the new Azam plot and the rest of the old Azam field means the on-farm results may be less reliable than the on-station ones.

Small but significant differences in total dry matter yield and days to 50% silking were observed for the new and old Azam. Interestingly, the old Azam had slightly shorter duration than the new. However, earlier National Cooperative Yield Trial results for 1983 in Pakistan indicated that Azam had similar days to silking performance to local maize (NARC 1983).

Highly significant differences between plant height of new and old Azam, and ear height, were measured in farmers' fields. Old Azam averaged 10% taller than new, and the ears averaged 12% higher. No significant difference could be detected between the variance or coefficient of variation of plant height between new and old Azam, nor for ear height.

On-Station Trials

The main results of the on-Station trials are reported in Table 5. In contrast with the on-farm results, no significant difference between the grain yield of new Azam and old Azam could be established. The yield of the local check matched the yield of the two types of Azam on-station.

The only responses for which significant differences could be established between the old and new Azam were plant height and ear height. For these two plant characteristics, a gradation appears to exist between the local maize, the old Azam and the new Azam. The local was almost 20 cm taller than the new Azam, and ears on average were some 15 cm higher. The old Azam,

Table 4. *Means of Yield and Plant Characteristics of Old and New Azam, On-Farm Trials, 1989*

Response Variable	Unit	Old Azam	New Azam	Significance
Grain Yield	t ha^{-1}	5.54	6.34	***
Stover Yield	t ha^{-1}	6.23	6.45	n.s.
Total Dry Matter	t ha^{-1}	10.5	11.4	**
Barren Plants	%	11.1	8.5	**
Days to 50% Silking		59.9	61.1	***
Plant Height	cm	244	222	***
Ear Height	cm	137	122	***
C.V. Plant Height	%	7.71	7.79	n.s.
C.V. Ear height	%	12.9	13.2	n.s.

Note: *, ** and *** denote significant difference between means at P = 0.10-0.05, P = 0.05-0.01 and P < 0.01, respectively, using pairwise t-tests as outlined in Norusis (1991) for all but C.V. The test for C.V. was that described in Anderson and Hazell (1989 p.9).

Table 5. *Means of Yield and Plant Characteristics of Old and New Azam, On-Station Trial, 1989*

Response Variable	Unit	Local Variety	Old Azam	New Azam	Significance
Grain Yield	t ha^{-1}	7.76	7.48	7.65	n.s.
Stover Yield	t ha^{-1}	11.5	11.8	12.6	n.s.
Total Dry Matter	t ha^{-1}	17.2	17.2	18.0	n.s.
Days to 50% Silking		65.2	64.9	64.3	n.s.
Barren Plants	%	6.0	8.1	7.5	n.s.
Plant Height	cm	198	191	181	*
Ear Height	cm	113	106	98	*
C.V. Plant Height	%	13.5	13.6	13.0	n.s.
C.V. Ear Height	%	21.7	20.7	20.7	n.s.

Note: *, ** and *** denote significant difference between means at P = 0.10-0.05, P = 0.05-0.01 and P < 0.01, respectively, using independent t-tests for the difference between means of old and new Azam for all but C.V. The test for C.V. was that described in Anderson and Hazell (1989 p.9).

which was presumably contaminated and mixed with local maize over time, falls about midway between the other two with respect to means of plant height and ear height, respectively.

The on-station results also failed to reveal any statistical difference between the variance or coefficient of variation of plant height for new and old Azam. The same was found for ear height.

Plant Characteristics and Number of Years Farmer had Grown Azam

For plant height and ear height, correlation analysis was undertaken with the number of years the farmer had grown Azam (recorded in the early stages of the field research). The calculated correlation coefficients were all found to be insignificant statistically. This implies that no smooth gradation existed between the measured plant characteristics and the number of years the farmer had grown Azam. The lack of a smooth gradation is probably attributable to the different methods employed to select Azam seed by participating farmers and the different conditions for contamination across farms.

Plant Characteristics and Method of Selection of Seed of Azam

Many farmers placed a high priority on large cobs (and tall plants in some cases) in their seed selection, while others emphasised other criteria (Table 3). Thirty one out of 50 farmers stated that large cobs or tall plants were either the 1st or 2nd most-important criterion for selecting their maize seed. The data for these farmers were grouped, with the remainder forming another group. Means of plant height, ear height and yields were calculated for each group. However, no statistical differences between the group means of variables were found when analysed this way. The differences in plant characteristics across farmers did not appear to follow a regular pattern in relation to farmers' seed selection methods.

Multiple Regression Analysis of Plant Characteristics

To test whether age of seed and method of seed selection might jointly be related to plant characteristics (plant height and ear height), multiple regression equations of the following form were estimated:

$$PHEIGHT = b_0 + b_1 \, AGE + b_2 \, DLARGE$$

where PHEIGHT = mean plant height for each row (cm)
AGE = age of old Azam (years)
DLARGE = binary variable for those farmers selecting seed based on large cobs or tall or large plants (1 if doing this, 0 otherwise).

An equation identical on the right hand side was also estimated for ear height.

The multiple regression equations both had R^2 near zero, implying no joint relationship existed between the two independent variables and the dependent variable(s), respectively, existed. This also suggests that no regular pattern of deterioration existed across age of variety and method of seed selection.

ASSESSING THE RATE OF VARIETAL DETERIORATION

Despite the lack of a smooth gradation in plant characteristics, an assessment of the rate of varietal deterioration can be made using means. The overall mean age of old Azam was 2.5 years, maximum of 4 and a minimum of 1. Taking the mean plant characteristics from the station trials for new Azam and for the local maize, it is possible to estimate the rate of varietal deterioration.

The main results are presented in Figure 3. This shows in percentage terms the difference between means of new Azam (at 0%), local maize (at 100%) and old Azam, for plant height and ear height. Thus with a mean age of 2.5 years, the old Azam had deteriorated by an average of 55% for the two characteristics combined. Following Hutchcroft (1959) it is likely that further deterioration of the old Azam would be rapid.

If the mean deterioration (%) were to follow a smooth regular pattern with average age of variety, it would probably trace the pattern of the logistic curve.[4] Assuming that the results in Figure 3 lie on the logistic curve (*i.e.* there is 55% deterioration after 2.5 years) and with a ceiling of deterioration of 100%, it is possible to predict when various levels of deterioration would occur, for different starting points. The results are presented in Table 6.[5]

The main conclusion to be drawn from Table 6 is simple. If the old Azam had deteriorated on average by 55% with an average age of 2.5 years, it is likely to be more than 95% deteriorated after 4 years. Thus, the difference between the old Azam and the local maize would be virtually negligible in the 5th cycle of the old variety.

IMPLICATIONS AND CONCLUSIONS

The rate of varietal deterioration based on certain distinguishing characteristics has been measured and found to be extremely rapid (implying more than 95% deterioration in 4 years). This was on farms where 80% of the total maize area was planted to the improved variety Azam and a similarly high percentage of Azam would have existed on neighboring farms (not surveyed). With such a high density of Azam, the remaining local maize would also have been contaminated by Azam, so that the local checks used could have displayed lower plant height and ear height than for local maize not crossed with improved varieties. Perhaps this tended to overstate the extent of deterioration in this study, through a double counting effect (while the old Azam is gaining height through contamination, the local maize in the area would be shortening). Only further testing with different local checks could answer that.

On farms where improved varieties are initially introduced and the area planted to them is much less than in the Swat study area, the rate of varietal deterioration would be even more rapid than found above. The improved varieties in farmers' fields would be likely to be 95% deteriorated within 3 years, depending on winds, cropping intensity, and farmers' seed selection methods.

Where the improved variety is adopted to near saturation, the rate of deterioration would be considerably less than observed in this study. With adoption near saturation, the remaining pool of local variety would tend to drift genetically strongly towards the improved variety. This has

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[4] The logistic curve is commonly employed in epdemiology to represent the spread of a disease, no different from the process of deterioration here. For details on the logistic curve see Griliches (1988, 28-31). The curve is represented by the formula

$$P_t = K/[1+e^{-(a+bt)}]$$

where P_t is the percentage contaminated at age t, K is the ceiling or upper limit on contamination (presumed to be 100% in this application), and a and b are constants which position the curve on the time scale and set the rate of growth, respectively.

[5] To do this we assume a minute amount of contamination in the new Azam (*e.g.* $P_t = 0.1\%$ when $t = 0$). From the formula in footnote 4, this implies that $a = -6.90675$. If $K = 100$ and $P_t = 55$ when $t = 2.5$, then $b = 2.84297$. Substituting these parameters into the logistic equation we can predict contamination percentages for different ages of old Azam.

Fig. 3 The Extent of Varietal Deterioration of Old Azam

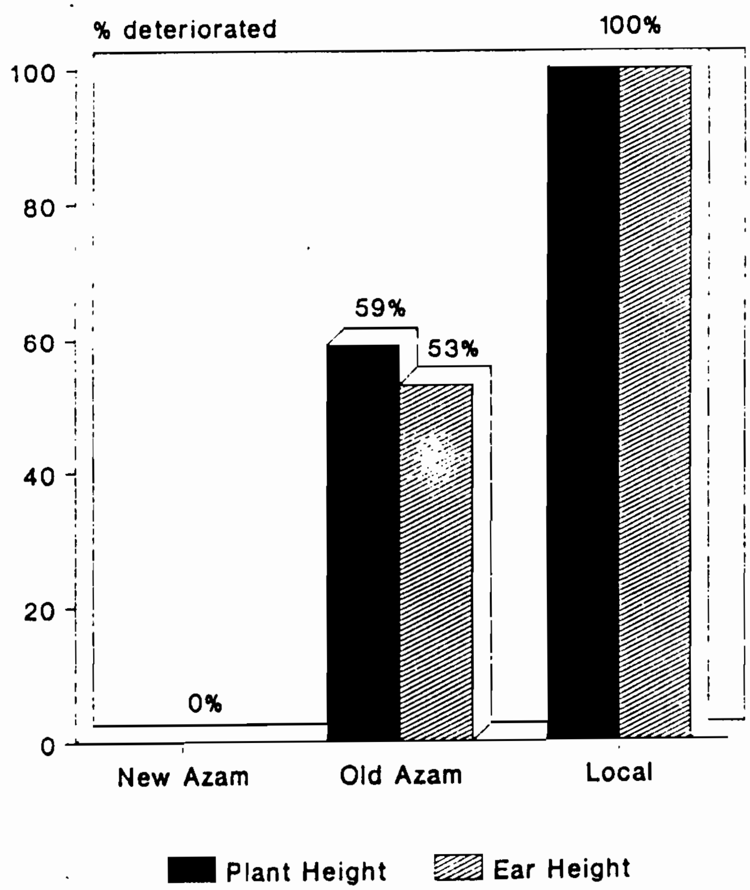

Table 6. *Predicted Percentages of Deterioration of Old Azam, under Three Different Levels of Contamination in the New Azam*

Age of Variety	Percentage Deterioration of Old Azam When: P_0=.0001%	P_0=0.1%	P_0=1.0%
yrs	%	%	%
0	0.0	0.1	1.0
1	0.0	1.7	6.4
2	6.9	22.8	31.9
3	95.3	83.5	76.1
4	99.9	98.9	95.6
5	100.0	99.9	99.3
6	100.0	100.0	99.9

Note: The predictions of 100.0% were close to that figure, and rounded up. P_0 can be considered as the extent of contamination in seed of new Azam, an unknown parameter in the prediction formula.

been found to occur in other locations and is one of the causes for concern about loss of genetic diversity in certain locations. However, evidence from Mexico refutes this argument because smallholder farmers are able to maintain landraces alongside improved varieties (Bellon and Brush 1993).

More precise seed industry strategies for open-pollinated varieties can be developed from studies such as this. Basically, the results suggest that rapid replacement of seed will be required in areas where farmers are growing improved open-pollinated varieties amongst fields of local varieties. For the Swat area, replacement every 3-4 years would be needed to ensure that the characteristics of the local variety are not dominated by the local maize. For most areas of Pakistan, the replacement should be even more rapid initially. More broadly, this study shows that open-pollinated varieties are likely to need replacement more frequently than perhaps thought previously. Much more evidence is required on this, and it can only come from studies along the lines of the one conducted.

One suggestion for advice to participating farmers. Farmers who are unsure about how to select seed from improved varieties in their fields should be encouraged to select seed from near the middle of their fields, and to select randomly from healthy plants. They should be told to avoid selecting for special traits if they want the variety to remain as genetically close to the original variety as possible.

There are several suggestions for future research. Firstly, have fewer dispersed on-farm trials and devote more effort to trials of all varieties in one location (preferably in a few locations where all varieties can be grown under fairly uniform conditions). Where on-farm trials are conducted, also grow a small plot of local variety (if the farmer will agree to this). Secondly, for the trials with all varieties in one location, grow more rows of local varieties and the new variety, relative to the old variety. This would make for a more efficient layout. Thirdly, seek to measure other plant characteristics which also are likely to be good indicators of genetic deterioration. Finally, do not bother to measure variability within plots.

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