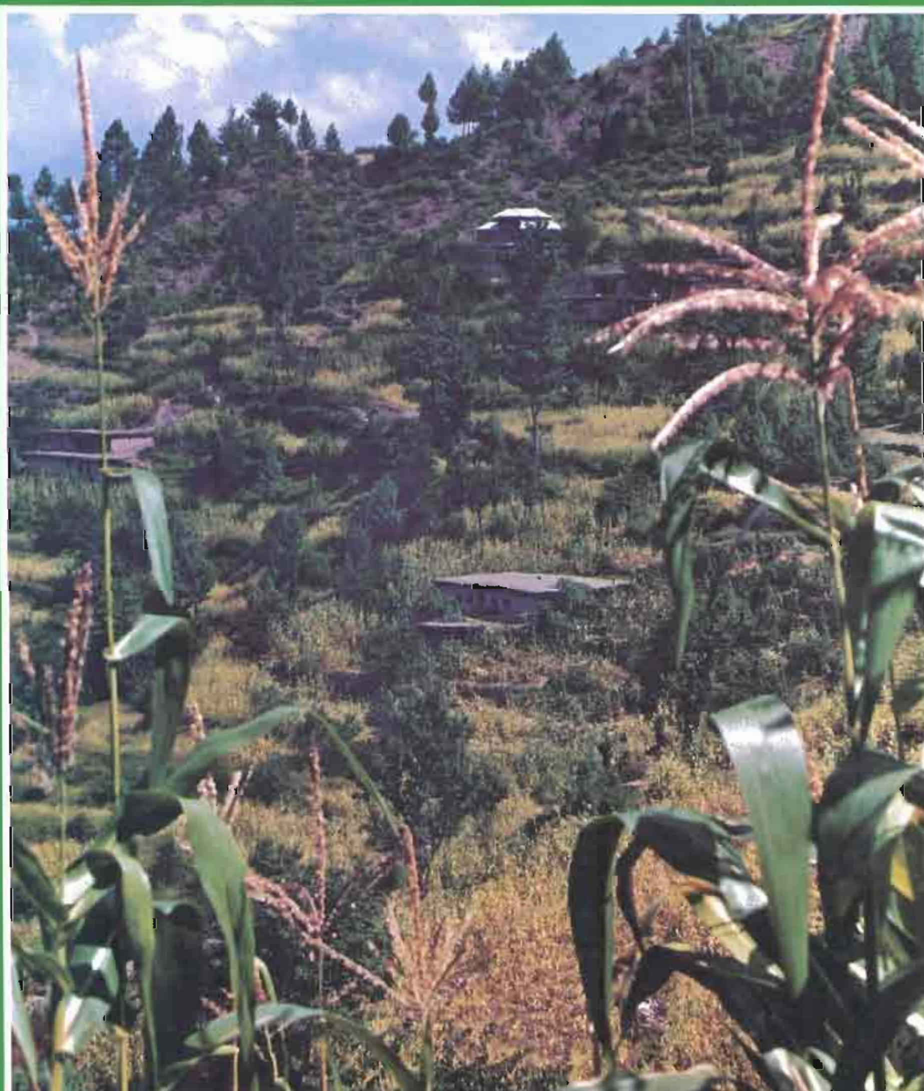
Maize Research and Development in Pakistan



PARC/CIMMYT Collaborative Program

Maize Research and Development in Pakistan

Pakistan Agricultural Research Council (PARC)/
International Maize and Wheat Improvement Center (CIMMYT)
Collaborative Program

The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on food production in developing countries. It is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). Donors to the CGIAR system are a combined group of 40 donor countries, international and regional organizations, and private foundations.

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Preface

Maize is frequently cited as a crop that was bypassed during Pakistan's green revolutions in wheat and rice, and more recently, cotton. While there is evidence that the returns to investments in maize research and extension have been positive for the country, these returns have not been nearly as great as in other crops (Nagy, 1984; Pray, 1983). Major factors which have reduced the potential returns from maize research have been a non-functioning maize certified seed industry, low input use, poor agronomic practices, and poorly developed market channels.

The purpose of this report is to review Pakistan's maize research and development activities over the past 30 years. The report begins with a look at maize—the fifth most important crop within Pakistan's national agricultural system. Next, the evolution of the national maize research system is reviewed, including the collaborative role played by the International Maize and Wheat Improvement Center (CIMMYT), which has had resident research staff posted in Pakistan for nearly 20 years. The report then goes on to survey the current status of maize production technologies, drawing on various farm-level surveys conducted under the Collaborative Program between CIMMYT, the Pakistan Agricultural Research Council (PARC), and the provincial maize research programs in NWFP and Punjab. Based on this information, best-bet strategies are identified for increasing maize productivity in the near term. The report ends with a series of observations about the current research and development infrastructure for maize and makes recommendations on how this system could be further improved to increase the productivity of maize in Pakistan.

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Maize in Pakistan

Maize in the World Economy

Maize ranks second to wheat in world cereal production, with milled rice third. During 1983-85, approximately 470 million tons were produced annually, with slightly more than one-third of this global harvest—170 million tons—being produced in the developing world (FAO, 1986). Maize is the most widely grown of the major crop species, with more than 70 countries planting maize on at least 100,000 ha, including 53 developing countries.

Maize is used in more ways than any other cereal: for human consumption, as a feed grain, a fodder crop, and for hundreds of industrial purposes. Its grain, stalk, leaves, cobs, tassel and silks all have commercial value in some settings.

On a global basis, two-thirds of all maize is used as animal feed, although it also constitutes a staple for the populace of several countries in Latin America, Africa and Asia. The most diversified use of maize is found in the USA, where over 1,000 products in a typical supermarket contain it in some form or another.

Importance of Maize in Pakistan

Maize accounts for 4.3% of the total cropped area and 2.5% of the value of agricultural output in Pakistan (Table 1). While the third most important cereal grain, it clearly is in a distant "third" place after wheat and rice.

Table 1. Area and Value of Major Crops in Pakistan

Crop	% total area	% total value
Wheat	42.5	33.3
Cotton	13.1	14.5
Rice	11 7	13.2
Sugarcane	5.3	12.3
Maize	4.3	2.5
Gram	5.9	1.4
Others	16.8	22.6

Source: Hamid et al. 1987

In 1984/85, Pakistan produced an estimated 1,028,000 metric tons of maize. The Northwest Frontier Province (NWFP) accounted for 55% of national production and the Punjab Province for 43%. Very little maize was produced in the provinces of Sind and Baluchistan. Maize was more prevalent within the farming systems of NWFP, accounting for some 37% of the total cropped area during the summer (Kharif) season (up to 75% of area in some districts) compared with only 6% of the total cropped area in the summer season for the Punjab (20-30% in some districts) (Pakistan, 1987). It tends to be more important among farmers with smaller landholdings, where its multiple grain and fodder uses make it a versatile element in the farming system (Table 2)

Table 2. Farm Size Distribution among Maize Producers in Selected Areas

Farm size (ha)	% total area		
	Central Punjab[1]	Swat Valley[2]	Islamabad[3]
< 2	17	87	66
2-5	65	—	26
5-10	15	13	—
10-15	2	—	8
> 20	1	—	—

Sources: 1/ Tetlay et al. 1987;
2/ Byerlee et al. 1988;
3/ Sheikh and Malik, 1987

Maize Area

Approximately 809,000 ha of maize is grown in Pakistan, almost entirely during the summer season. NWFP, with approximately 450,000 ha, has the largest maize area, followed by Punjab Province, with approximately 350,000 ha (Table 3). Only about 20,000 ha of maize is planted in the Sind and only 3,600 ha in Baluchistan. Though not included in Pakistan's agricultural statistics, maize is an important crop in Azad Jammu and Kashmir (AJK), where some 122,000 ha are planted, and in northern areas.

Early maturing varieties of wheat and maize developed during the past two decades have led to greater intensification in cropping patterns. The number of farmers in NWFP and northern Punjab that employ maize/wheat rotation systems has steadily increased.

Table 3. Maize Area by Province and Division, 1984-85

Province/division	Irrigated	Rainfed	Total
	Hectares		
NWFP	**223,100**	**219,800**	**442,900**
Hazara	37,300	122,400	159,700
Kohat	4,200	7,700	11,900
Malakand	47,000	78,900	125,900
Peshawar	95,200	3,400	98,600
D.I Khan	17,000	1,900	18,900
FATA	22,400	5,500	27,900
Punjab	**288,700**	**53,700**	**342,400**
Faisalabad	104,900	800	105,700
Multan	66,100	—	66,100
Rawalpindi	12,900	44,100	57,000
Lahore	35,800	—	35,800
Sargodha	26,600	600	27,200
Gujranwala	16,400	8,000	24,400
Bahawalpur	19,800	200	20,000
D.G Khan	6,200	—	6,200
Sind	**20,100**	**—**	**20,100**
Hyderabad	18,000	—	18,000
Sukkur	2,100	—	2,100
Baluchistan	**1,700**	**1,900**	**3,600**
Quetta	1,600	1,900	3,500
Sibi	100	—	100
Total Pakistan	**533,600**	**275,400**	**809,000**

Source: Ministry of Food, Agriculture & Cooperatives, Food and Agriculture Division (Planning Unit), Islamabad

Principal Production Environments

Eighty-four percent of the maize production in Pakistan is concentrated in two principal geographic clusters: 11 Districts in NWFP/northern Punjab and 9 Districts in the central Punjab. These two regions respectively account for 56% and 28% of the total national maize area (Figure 1, Map). Maize is primarily a summer-season crop grown in lowland and mid-altitude agroecological zones in these two provinces. (A more detailed description of the principal agroecological zones in which maize is grown in Pakistan is presented in Chapter 5.)

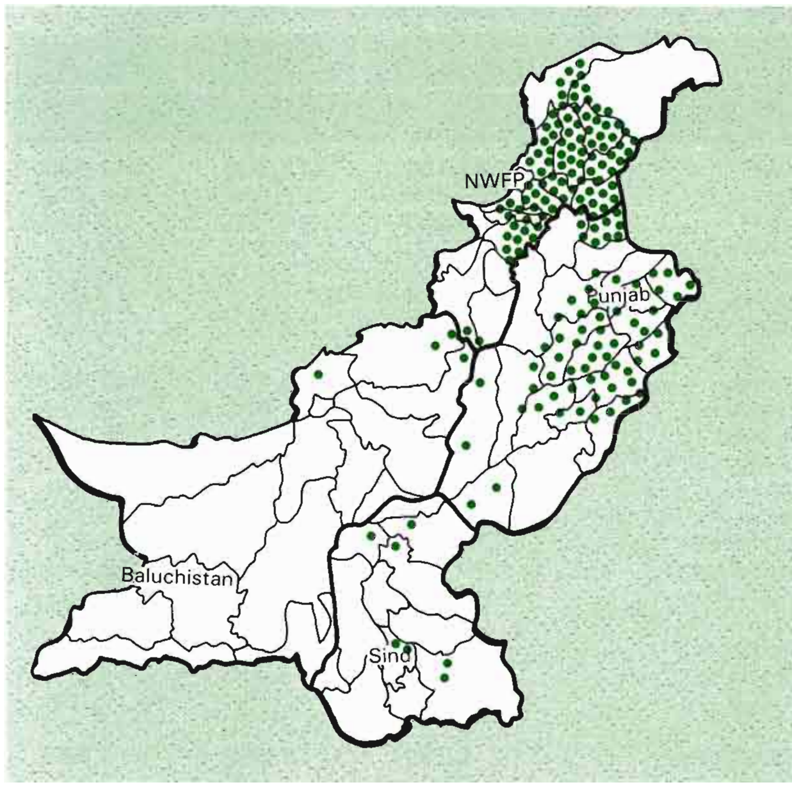


Figure 1. Maize Production Areas of Pakistan

During the summer months, lowland areas are difficult environments for maize production. High temperatures frequently inhibit pollination, increase respiration and transpiration rates, and limit dry matter accumulation. Pakistan's hot monsoon climate has the added disadvantage of frequent cloudy weather which reduces photosynthetic production and, therefore, grain yield.

Approximately 65% of the maize area in Pakistan has access to irrigation; the remainder is farmed under strictly rainfed conditions. In both cases, however, farmers rely on monsoon rains for moisture. Even though most of the nation's maize area is officially designated as irrigated, the maize crop is often subjected to heat and drought stress due to poor water management and heavy transpiration. Pronounced water stress during flowering, pollination, or grain filling frequently causes significant yield reductions.

Maize grown in lowland areas of Pakistan also faces heavy pressure from foliar diseases such as *Helminthosporium maydis* and *H. turcicum*, and stalk and ear rots caused by *Fusarium* spp. At the higher elevations, temperate-zone diseases such as rust (*Puccinia sorghi*) and head smut (*Sphacelotheca reiliana*) can also cause economic losses. Among insects, the maize stem borer (*Chilo partellus*), cutworm (*Agrotis ipsilon*), and shoot fly (*Atherigona* spp) are the most serious pests.

Finally, maize in Pakistan is cultivated as a multi-purpose food and forage crop, generally by resource-poor farmers using marginal land, few purchased inputs (as compared to wheat, rice or cotton), and with significant portions of the harvest destined for home/farm consumption.

Maize Utilization

It is estimated that 70% of the Pakistani maize crop is consumed on the farm; 10% is marketed locally (payment to landlords, charity, local sales); and 20% is sold to grain merchants in the organized wholesale market (Amir, 1986).

Preference for grain type and color varies in different areas of the country. In NWFP, farmers and consumers prefer white, flinty grain (most varieties today have white, semi-dent grain). In the Punjab, color is less an issue and most varieties are yellow-grained semi-dents. Some yellow-grain hybrids, based primarily on U.S. corn belt materials, are grown in central and southern Punjab. In addition, small amounts of popcorn and waxy maize are sown by contract growers in the Punjab for Rafhan Maize Products, Ltd.

Maize is a major food source, especially among small-scale farmers, in NWFP and the northern portion of Punjab Province. In this northern zone of Pakistan, maize consumers grind the grain into flour to bake *chapatis*. Maize is also frequently eaten as roasted green ear corn. It is likely that per capita maize consumption in NWFP ranges from 60 to 125 kg/year, depending on the district.

Maize is far less important as a foodstuff for people in central and southern Punjab Province—the other principal geographic zone where the crop is grown. There, household consumption of maize is generally slight and most often in the form of roasted green ears.

Increased wheat production in Pakistan and the lower price of wheat in the marketplace have led to a growing substitution of this cereal for maize in the diets of poor consumers. More and more maize farmers now find it economical to sell their maize grain to buy wheat flour.

Maize fodder is a very important commodity in Pakistan. In NWFP, the common practice in most fields is to thin green plants progressively (up until flowering) from the plots to feed farm animals. The remaining plants are harvested for grain and the stover used as livestock feed. In contrast, in central Punjab the harvest from 32-40% of the maize area is used for animal fodder. In fields where the crop is allowed to reach physiological maturity, much of the grain is used for livestock feed or sold through the organized market for food, feed and industrial purposes.

Trends in Maize Production, Area and Yields

Maize production has doubled during the past 20 years, from 525,000 metric tons in 1966/67 to 1.08 million tons in 1986/87, increasing at a rate of 3.5% per annum (Figure 2). While maize production in Pakistan has grown faster than the population, its growth is much slower than that of wheat production (5.5% per annum) over the same time period.

Most of the growth in Pakistani maize production has been due to increases in area rather than yield. The area devoted to maize production in Pakistan has steadily expanded, from 500,000 ha in 1969/70 to 800,000 ha in 1985/86 (Figure 3). According to government statistics, the average national maize yield has increased from 1,025 to 1,250 kg/ha over the same time period (Figure 4).

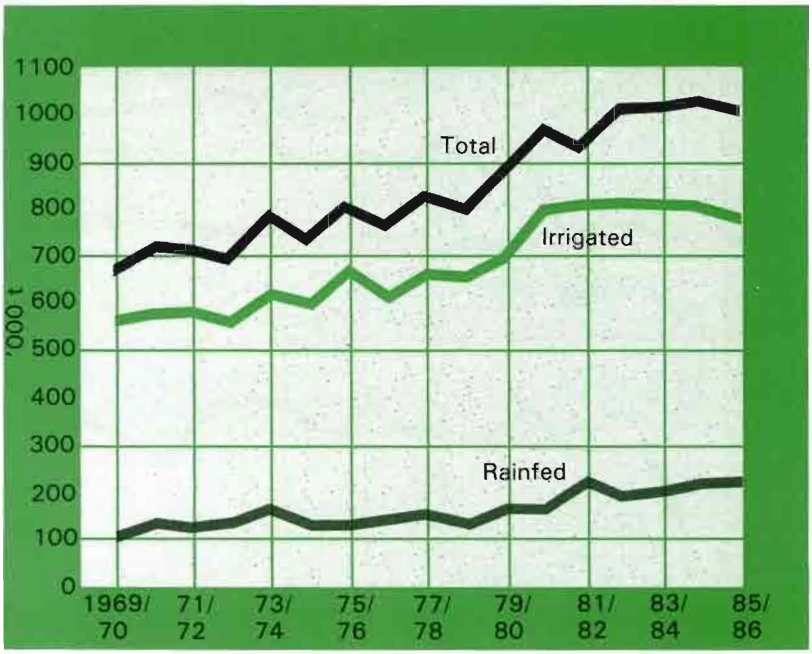


Figure 2. Maize Production in Pakistan by Type of Moisture Regime

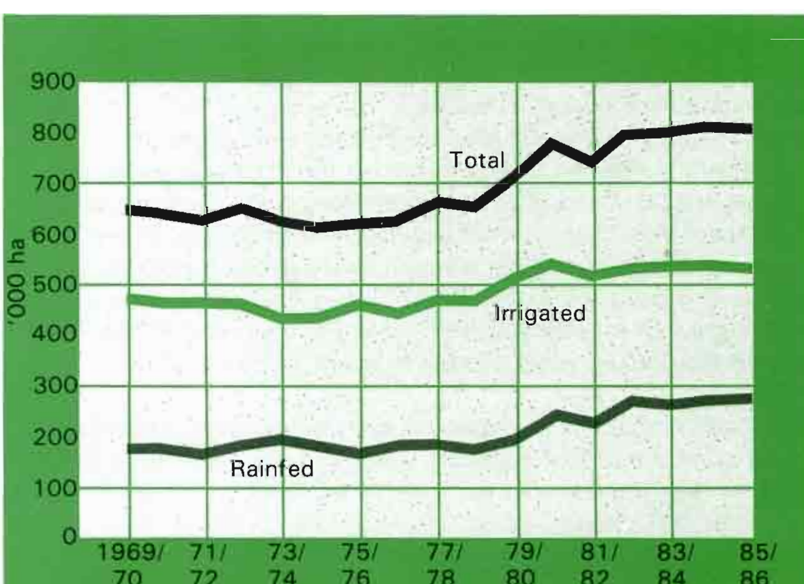


Figure 3. Maize Area in Pakistan by Type of Moisture Regime

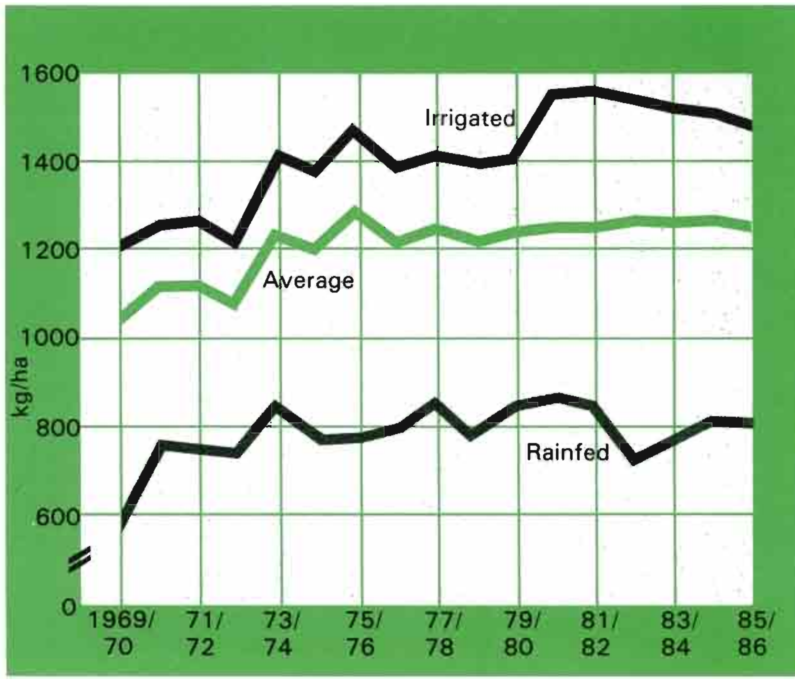


Figure 4. Maize Yields in Pakistan by Type of Moisture Regime

Growth rates in maize area and yields during the past four decades have fluctuated wildly, with area expansion accounting for most of the overall increases in maize production during the past 35 years (Table 4). Area expansions were especially significant during the 1960s in Punjab Province and during the 1970s and 1980s in NWFP. In both Punjab Province and NWFP, significant yield improvements correspond to periods where chemical fertilizers, mainly nitrogen, were adopted on a large scale. This occurred in the Punjab during the 1960s, when maize yields grew at a healthy rate of 3.1% per year, and in NWFP during the 1970s, when yields increased 1.6% per year.

It is quite probable that maize yields have improved more than reported in the official statistics. Extensive farm-level yield (crop cut) surveys were conducted in selected districts of NWFP by the

Table 4. Growth Rates in Maize Area and Yields, 1950-86

Period	Indicator	% annual growth rate		
		Punjab	NWFP	Pakistan
1950-52 to 1960-62	Area	3.5	1.8	2.8
	Yield	-0.5	-1.4	-1.1
1960-62 to 1970-72	Area	2.1	3.5	2.9
	Yield	3.1	1.1	2.1
1970-72 to 1980-82	Area	3.1	1.5	2.2
	Yield	0.4	1.6	1.3
1977-79 to 1984-86	Area	1.9	4.3	3.0
	Yield	0.02	0.6	0.3

Sources: Agricultural Statistics of Pakistan various years

PARC/CIMMYT maize program and NWFP researchers (Table 5). These surveys consistently recorded farm-level yields 50 to 200% above those listed in the official statistics. Although the surveys may overstate the district yields 10 to 15% as a result of using an extremely small sampling frame, the large disparity with the official statistics still cannot be reconciled.

Table 5. Comparison of Data on Grain Yields in Selected Districts of NWFP

District	Official yield statistics 1983-85	Crop cut surveys 1983-85
	t/ha	
Mansehra	0.8	3.0
Swat	1.3	4.1
Mardan	1.6	2.5

Source: Byerlee and Hussain, 1986

The widespread use of maize for fodder in Pakistan is not represented in official statistics, which only take maize grain yield into account. This significantly affects the reliability of national yield and production data. In a private study conducted by Rafhan Maize Products Ltd. in 1983, it was estimated that only 52% of the maize area in the Punjab Province and 78% of the maize area in NWFP is harvested for grain (Personal Communication, Khan

Bahadur). A recent PARC/CIMMYT exploratory survey in central Punjab estimated that 40% of the area was harvested prematurely for maize fodder. When yields are calculated on the basis of the net area harvested for grain, average yields increase considerably (Table 6).

Table 6. Estimated Net Maize Area Harvested for Grain in NWFP and Punjab Province

Use	NWFP	Punjab	Total
	% total area		
Grain crop	89	68	79
Fodder crop	11	32	21
Thinned/damaged	12	23	16
Net harvested for grain	78	52	72
Average yield	Kg/ha		
Official	1,252	1,333	1,254
Estimated area harvested for grain	1,598	1,960	1,740

Source Rafhan Maize Products, Ltd 1983

In some areas of NWFP, maize is also grown explicitly as a specialized fodder crop. The normal practice, however, is to use it as a multipurpose grain/fodder crop. In high elevation areas (1,000-1,800 masl), farmers typically start off with population densities of over 200,000 plants per hectare and, beginning at the six-leaf vegetative stage, progressively thin the stand to 70,000 plants per hectare by harvest (Khan et al., 1986).

Use of Improved Genotypes

The maize varieties grown in Pakistan are mixtures of local landraces and improved open-pollinated varieties based on germplasm obtained from temperate zones and, more recently, from tropical areas. Pakistan does not have a well-organized maize seed industry and relatively little certified maize seed is produced. Official prices for maize seed are among the lowest in the world; a factor which has contributed significantly to the current plight of the nation's maize seed sector

Including the hybrid seed produced by Rafhan Maize Products, Ltd., approximately 1,300 tons of OPV seed and some 500 tons of hybrid seed was produced in Pakistan in 1986, sufficient to plant about 4-5% of the total area (Table 7). If a broader criterion—that of certified commercial seed bought within 10 seasons—is used to estimate the area planted to improved genotypes, then approximately 10% of the total maize area in Pakistan is planted to improved varieties and hybrids, constituting one of the lowest levels of adoption in the developing world (Table 8)

Table 7. Public Sector Sales of Improved Seed[1/]

Year	Punjab	NWFP	Total Pakistan	Estimated area ha	Portion of national maize area %
	tons				
1971-73*	190	125	315	7,875	1
1973-75*	355	130	485	12,125	2
1975-77*	970	105	1,075[2]	26,875	4
1977-79*	465	15	480	12,000	2
1979-81*	430	65	495	12,375	2
1981-83*	935	10	945	23,625	3
1983-85*	1,225	15	1,240	31,000	4
1985-86**	1,490	80	1,570	39,250	4

Source Agricultural Statistics of Pakistan 1986

*/ Two-year averages: e.g. 1971-72 and 1972-73

**/ Single year data

1 Rafhan Maize Products, Ltd has produced hybrid maize seed for its contract growers since 1971, which is not included in official statistics; this amount ranged between 400-600 t during 1984-87, sufficient for 10 to 15,000 ha

2 During this fiscal year, 33t and 2t of maize were also produced in Sind and Baluchistan provinces, respectively

Maize seed is also produced by the Punjab Seed Corporation (PSC). The two provincial maize research institutes—the Cereal Crops Research Institute (CCRI) in NWFP and the Maize and Millets Research Institute (MMRI) in Punjab—regularly produce and sell small amounts (20-50 tons) of improved seed (OPVs and hybrids) to farmers who come to their stations.

Although the formal commercial maize seed production system in Pakistan produces limited tonnages of certified seed, the nation's research and extension services have attempted to diffuse the seed of improved genotypes through various ad hoc seed multiplication campaigns in NWFP and Punjab since the early 1970s.

Table 8. Maize Area Planted to Improved Seed in Selected Developing Countries, 1986

Country	Maize area '000 ha	% planted by type			Price ratio seed:grain	
		Own seed	Impr. OPV*	Hybrid	Imp. OPV	Hybrid
Pakistan	801	90	8	2	1.3	3.5
Thailand	1709	41	52	5	5.7	18.1
India	5896	82	5	13	3.4	3.8
Philippines	3361	82	16	1	4.3	3.9
Guatemala	777	40	24	36	2.9	3.7
Zimbabwe	1450	23	1	76	1.9	3.9
Egypt	805	58	32	10	1.1	1.4

* OPV seed with true-to-type characteristics purchased within last 10 seasons

Source: 1987 CIMMYT World Maize Facts & Trends 1986, Report Three: Economics of Maize Seed Production in Developing Countries

These campaigns have relied on planting hundreds of small seed multiplication plots on farmers' fields in maize-growing areas and advising cooperating farmers on the best methods for selecting grain to be used as seed. They have been effective in stimulating farmer-to-farmer distribution of reasonably pure seed. As a result of these campaigns, it is likely that 50 to 60% of the total maize area is planted to improved maize with germplasm from crosses between local landraces and improved varieties.

Fertilizer Use

Official fertilizer use figures for maize are not specifically recorded by the agricultural statistics services. However, extensive farm-level surveys conducted by PARC/CIMMYT in various districts of NWFP and in the central Punjab reveal that approximately two-thirds of all maize growers now use chemical nitrogen fertilizers (70-80 kg N/ha) and about one-quarter use phosphorus (15-30 kg P/ha) (Table 9), along with the traditional farmyard manure. In addition, there is often fertilizer left over from crops that precede maize; e.g., when maize is planted after forage legumes, potatoes, or wheat. Fertilizer-use rates on maize, however, are not as high as on wheat and other crops which are more significant in farmers' cropping patterns.

Mechanization

Comparatively high numbers of farmers use tractors for land preparation and maize shelling (Table 10). The use of tractors is more widespread in NWFP in the low- and mid-altitude production areas. Among the canal colony farmers of central Punjab Province, animals are the main source of traction for land preparation. More than 75% of maize farmers in both areas use mechanical maize shellers.

Table 9. Estimates of Average Fertilizer Use in Maize

Province/District	N	P	Total
	kg of nutrient/ha		
NWFP			
Mardan	81	15	96
Mansehra	67	12	79
Swat	77	28	105
Punjab Province			
Sahiwal/Faisalabad	73	27	100

Source: Wedderburn et al. 1984

Table 10. Use of Animal and Tractor Power in Maize Land Preparation in Selected Districts of NWFP and Punjab Province

Province/District	Power Source		
	Animal	Tractor	Mixed
	% farmers using		
NWFP			
Mansehra (1984)	38	62	—
Mardan (1984)	32	68	—
Punjab Province			
Toba Tek Singh/ Faisalabad (1986)	63	28	9

Sources: Byerlee and Hussain 1986; Tetlay *et al.* 1987

Commercial Marketing Channels

Surplus maize is produced in both of the major maize-farming zones, although less market surplus is generated in NWFP. Farmers sell surplus maize to local grain agents (*beoparis*) at the farmgate or to commission agents in the larger cities. The organized market economy for maize involves the sale of approximately 200,000 tons of grain—20% of official national production (Table 11).

Table 11. Commercial Sales and Uses of Maize

Industry/purpose	Amount (t)
Wet-milling industry	101,900
Rafhan Maize Products	(71,900)
Other wet-millers	(30,000)
Poultry feed	100,500
Food Commodity Corporation	10,500
Seed	5,000
Total	**217,900**

Sources: Agricultural Marketing & Grading Department, GOP Karachi; Rafhan Maize Products Ltd, 1987

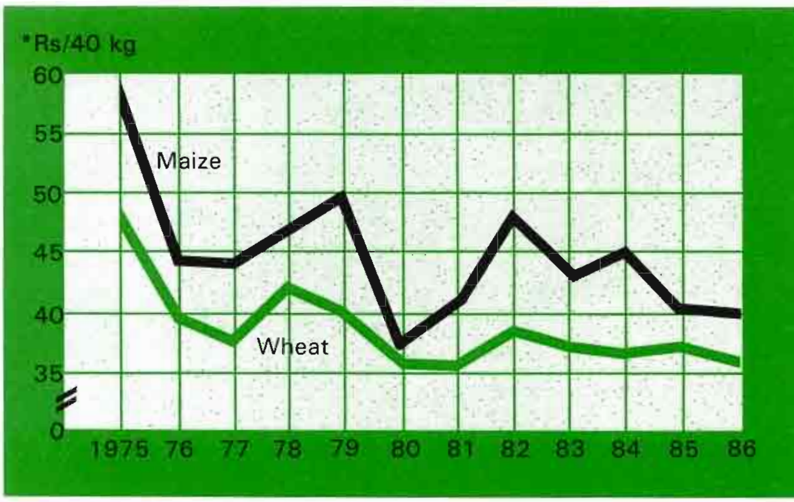
Some 100,000 tons of maize grain is used annually in the wet-milling industry, primarily to produce starch, sweeteners and cooking oil. Several by-products of the wet-milling process, such as gluten feed and oil meal, are used in the formulation of complete manufactured mixed feeds. Rafhan Maize Products, Ltd. is the largest wet-miller in the country and the dominant buyer, accounting for approximately 33% of all maize grain traded in Pakistan. Rafhan's dominance in the marketplace and its own 100,000 ton storage capacity—the largest in the country—gives it a very strong influence over the price of maize in the wholesale marketplace.

Rafhan augments its purchases in the organized market through its own program of contract maize production, which includes specialty maize types, such as popcorn and waxy maize, needed to produce its industrial and food product lines. At present, Rafhan contracts the production of approximately 25,000 tons of maize per year (35% of its total requirement), all during the spring season. This maize is purchased at a pre-established price and on the cob.

Another 100,000 tons is purchased by the poultry industry for feed. Because there are many substitute feedstocks, maize replaces other feed grains only when its price falls. Thus, the demand for maize in poultry feed essentially provides a cushion on prices.

Price Trends

Because less improvement has been achieved in maize productivity than in that of wheat, its price in the marketplace has tended be 15% above that of wheat during 1975-85, with the range varying between 105 and 124% of the price of wheat (Figure 5) This maize:wheat price ratio is considerably different from that of international markets, where maize historically has been priced at 80% of wheat.



* converted to 1975 rupees with the wholesale price index

Figure 5. Average Annual Real Wholesale Prices of Maize and Wheat in Pakistan, 1975-86

In the 1970s, the price of maize fluctuated more in the marketplace than that of wheat or rice. However, in the 1980s the real price of maize has been remarkably stable, even though maize is not supported by a government procurement price—the effective official floor price of Rs 34.50 per maund (40 kg) has prevailed since 1976. In 1985-86, maize traded at an average price of Rs. 105 per maund. The greater month-to-month price fluctuations which occur in the maize market are primarily a result of its small size relative to the wheat and rice markets. However, few farmers (at least in NWFP) report difficulties in selling maize at expected prices in recent years (Byerlee and Hussain, 1986)

Factors on both the supply and the demand side appear to have stabilized the price of maize. On the supply side, the switch to wheat by farmers that previously relied on maize as a principal food has increased the marketable surplus and reduced year-to-year variability On the demand side, now that the majority of surplus maize sales is destined for industrial uses and poultry feed, the market has become more stable.

The Evolution of National Maize Research

Early Maize Research Efforts

Maize research in Pakistan dates back more than 30 years. Following World War II, a number of U.S. hybrids were introduced. Maize breeding research efforts began in the early 1950s and produced several conventional hybrids based on U.S. corn belt inbred lines crossed with varieties and inbred lines derived from local materials. Although these hybrids were well adapted and high yielding, the lack of a seed industry capable of reproducing hybrids resulted in little diffusion of these genotypes at the farm level. This led to a redirection in maize improvement research in the mid 1960s. Hybrid research was, for the most part, discontinued and the emphasis was shifted to the development of improved open-pollinated varieties (OPVs), also commonly referred to as ''synthetic'' or ''composite'' varieties. These OPVs were based primarily on temperate-zone germplasm, largely from the USA, crossed in varying degrees with local materials. The priority on OPVs was motivated by the greater ease and lower cost with which seed production could be accomplished (in comparison with hybrids) and the fact that OPV seed could be saved (unlike the case of conventional hybrids) by the farmer for planting subsequent seasons.

By the early 1970s, several new OPVs had been developed by the research service and released for general cultivation. While greater success was achieved in OPV seed production than in that of hybrids (the maximum hybrid seed production achieved in a season was enough to cover only 1% of the total maize area), national yields remained at very low levels and the impact of maize research was viewed with dismay by research administrators and agricultural policymakers.

During the 1970s, the research emphasis shifted somewhat away from germplasm development toward agronomy issues. Greater emphasis was placed on developing and extending ''recommended'' packages of production practices—along with the new genotypes—to farmers. Hundreds of on-farm experiments were conducted and the resulting packages of production technologies were demonstrated on thousands of farms. Even so, average yields continued to hover around 1 t/ha, despite researchers' claims that their technological packages could double or even triple farm-level production

While the packages were agronomically sound, they did not take into consideration the role of maize within the farming system. Though many farmers adopted new varieties when they could get them and increased their use of nitrogenous fertilizer, other central elements of the recommended production packages—line planting, lower plant densities for optimal grain production, and chemical weed control—were rarely adopted. Furthermore, the diffusion to farmers of certified seed of improved genotypes was erratic and thus unreliable.

In the mid 1980s a new approach in maize research began to take shape. While still in its infancy, and by no means universally embraced nor institutionalized, this new approach gives greater emphasis to on-farm research with a farming systems perspective; i.e., maize is simply viewed as another of several enterprises within the farm operation. In this research orientation, maize production constraints are identified from the vantage point of the farmer, and research priorities are ranked according to farmers' needs and circumstances.

Initial Emphasis on Hybrid Development

One of the first major breakthroughs in modern agricultural research came with the discovery of the heterosis (hybrid vigor) which results when different genotypes with high combining ability are crossbred. By the 1920s research and production techniques to produce double-cross hybrids economically on a commercial scale had been perfected.

The fact that hybrids have closed pedigrees (that is, they are protected against being copied) and need to be regenerated each year from the principal crosses to avoid the loss of vigor in the F2 generation provided the needed impetus (profit) for the establishment of hybrid seed companies in developed countries. These companies were instrumental in the diffusion of the new, high-yielding genotypes during the late 1930s and 1940s. Combined with the development of low-cost artificial fertilizers, this research breakthrough revolutionized maize production in the USA and, later, in other temperate-zone countries.

The superiority of the U.S. corn belt hybrids influenced the maize breeding programs of other countries, including Pakistan. With the help of USAID (then ICA), hybrid breeding work, which had been discontinued after independence, was reactivated in 1952 at the Central Research Station in Yousafwala, Sahiwal. (A hybrid program was also started in 1956 in NWFP.) The reactivated hybrid maize program of West Pakistan began its work by evaluating several American hybrids as potential candidates for direct introduction. A number of these gave encouraging results, especially U.S. 13 (a yellow dent) and Indiana 909 (a white dent). While high-yielding, these hybrids lacked disease resistance under Pakistani conditions. Such resistance, it was hoped, would be found in local germplasm developed previously by Pakistani scientists.

The first locally produced hybrids from this research effort were two yellow, double-cross genotypes with semident grain, named DC 59 and DC 697, developed at the Central Research Station, in Yousafwala, Punjab. Their makeup consisted of 75% local and 25% U.S. corn belt germplasm, and Dr. Yousaf Chaudhri, a young breeder at the time, was involved in their development.

In 1959, DC 59 was released for commercial production. To overcome the problems of seed production, a seed project was launched in 1960 with funding from the USA. Seed multiplication farms and processing facilities were established at Yousafwala in Punjab and Mardan in NWFP and the two officers-in-charge were sent to the USA in 1963 for FAO-sponsored training in seed technology.

Despite the investments made in the hybrid breeding program and in seed production facilities, little certified hybrid seed was produced, and what was produced was generally of low quality. Furthermore, the initial hybrids were based on American materials and had a yellow dent grain which lacked commercial appeal in Pakistan (and even the Punjab, at that time), where white flints were the popular grain types. The hybrids were also late-maturing compared with local varieties, and thus did not "fit" well in the various farming systems in which maize was grown.

The Hybrid vs Open-Pollinated Variety Debate

Though hybrids had become the standard in most maize improvement programs around the world by the 1950s, renewed methodological work in population improvement had shown that more rigorous selection methods resulted in high-yielding "synthetic" OPVs with good uniformity and a yield potential nearly equal to that of hybrids.

Many maize breeders working in developing countries, including those of the Rockefeller Foundation, became advocates of OPVs and believed that open-pollinated plant types could be developed that would have yields equal or superior to those of hybrids under the resource-poor production conditions typical of most Third World farmers. In addition, because the populations used to extract OPVs were undergoing continuous improvement with every cycle of selection, they believed that progress could be made for yield as well as other characteristics using a population improvement/OPV program, as in conventional hybrid development programs.

Other than the 2-3% of maize plants that self-pollinate, a field of an open-pollinated maize variety in reality represents many different ''hybrid'' combinations with a spectrum of genotypes ranging from high to low combining ability (Izuno, 1972). In contrast, a traditional F1 hybrid represents a fixed-line selection of a superior fraction of genotypes from populations with high combining ability. But to get at that superior fraction and make a conventional hybrid, 6 to 8 cycles of breeding are generally required for inbred line development and testing for combining ability. Furthermore, an F1 hybrid is basically static (the dynamics comes in the selection of inbred lines). Once developed, the main idea is to maintain its constituent inbred lines, so the hybrid can be made repeatedly with the same uniform characteristics. In theory, an improved version of an OPV is developed from each cycle of population improvement. For these reasons, some maize breeders believed that improved OPVs could be developed at such a rate that they would be generally superior to the more static hybrids already in commercial use for several years.

The use of OPVs was especially appropriate for developing-country maize producers, who were mostly small farmers not accustomed to purchasing production inputs such as fertilizer and improved seed. In addition, farmers could help to overcome the lack of maize seed programs by disseminating improved germplasm among themselves. In contrast to hybrids, which require careful and timely detasseling, a seed production field of an open-pollinated variety can be grown in much the same manner as a commercial field.

Discontinuation of the Hybrid Program

By the late 1950s, Dr. E.W. Sprague, team leader of the Inter-Asian Corn Program (IACP) headquartered in India, and his colleagues had produced their first improved OPVs. Extensive on-farm testing showed that these genotypes were equal—and sometimes even better—in yield potential to Indian hybrids under the low-input conditions characteristic of maize production in that country.

In 1963, the IACP was extended to Pakistan, and Dr. Sprague began to make regular visits to the country, where he observed the difficulties experienced with hybrid seed production and distribution. What Sprague saw in Pakistan added to his conviction that OPVs were a far more viable way to improve maize production in Pakistan than a strategy based on hybrids. Furthermore, he knew that some of the OPVs recently developed in India were suited to the low-elevation zones of Pakistan. The introduction of these first OPVs into Pakistan makes an interesting story (Swegle, unpublished manuscript, 1970).

Two USAID agricultural advisors in Pakistan, Staley Pitts and Curry Brookshire, happened to meet Sprague in India in 1964 and heard about the virtues of J-1, one of the first improved OPVs developed by Sprague and his colleagues in India. J-1 was a late-maturing, yellow-grain material based on 22 varieties of South American and Indian origin. While not the preferred grain type, Sprague thought J-1 had potential for Pakistan. He went to Pakistan in January of 1965 to discuss the merits and methodologies of developing OPVs with Dr. A.G. Bhatti and other Pakistani scientists (especially Dr. A.R. Chaudhry in Punjab and Dr. Khan Bahadur in NWFP).

It was decided to test J-1 on farmers' fields in central Punjab. Twelve kilograms of seed were sent to Pakistan via the diplomatic pouch and Pitts planted it out-of-season in February, 1965 (one of the first times that maize was planted in spring). With the June harvest, Pitts had enough seed to plant about 40 ha. He distributed this seed to 100 farmers in the area for a series of one-acre (0.4 ha) demonstration/seed-increase plots planted in the normal maize-growing kharif season. The yield of J-1 was far superior to that of local varieties; thus, the OPV was recommended for general cultivation.

During 1966 and 1967, J-1 was increased on a large scale in the Punjab and NWFP using spring and summer cycles, and enough seed was on hand in 1967 to plant 200,000 ha in the kharif season. Caught up in the enthusiasm of the accelerated wheat and rice production campaigns, Pakistani maize farmers also agreed to plant J-1 and follow some of the recommended production practices, especially the use of nitrogenous fertilizer. With favorable growing conditions in kharif 1968, a 20% increase in total maize area, and widespread use of J-1 seed and nitrogenous fertilizers, national production jumped from 505,000 to 745,000 tons. The next year, however, because of drought and less fertilizer use, national production dropped to 620,000 tons.

Sprague, Pitts and others tried to promote the idea of giving priority to the development of OPVs in Pakistan. Bhatti, however—who had been working with hybrids for more than a decade—was convinced that they should remain the basis for the nation's varietal improvement work, based on their inherent yield potential advantage over OPVs. Bhatti argued that the government should develop a functional maize seed industry rather than scrap its superior hybrid breeding strategy.

Nonetheless, arguments about the logistical drawbacks of hybrid seed production and benefits of OPVs for the small farmer were so convincing to policymakers that the hybrid program was officially de-emphasized in 1965, a decision still lamented by many veteran maize researchers. While J-1 would be used initially, an OPV improvement program was started in 1965 to develop varieties more suitable to Pakistan. Synthetic 66-white and Synthetic 200-yellow were the first results of these national efforts in OPV development.

West Pakistan's Accelerated Maize Improvement Program

In 1967, the government of West Pakistan, encouraged by the successes of the Accelerated Wheat and Rice Improvement Programs sponsored by the Ford Foundation, also asked this institution for assistance in launching an Accelerated Maize Improvement Program. The Ford Foundation turned to CIMMYT for technical assistance on the project and in 1968 the first resident maize advisor, Dr. Takumi Izuno, took up his post in Pakistan. Izuno's charge was to assist Dr. A.G. Bhatti, who had been named as Director of the West Pakistan Maize & Millets Improvement Project, in developing a comprehensive maize improvement program for the province. The principal researchers in this scheme were Mr. M.H. Shah and Dr. Khan Bahadur at Tarnab, NWFP, and Dr. Bhatti and Dr. A.R. Chaudhry at the Central Research Station at Yousafwafa.

Collectively, Izuno and the Pakistani scientists mapped out a maize improvement strategy involving both OPVs and hybrids. Because of seed production constraints, the immediate emphasis would be on OPVs, which yielded better than local varieties and could be developed relatively quickly. However, it was agreed that hybrids were to be gradually introduced as seed production and distribution conditions improved.

Because of the narrow genetic base of maize materials in West Pakistan, the first priority was to broaden the germplasm base. During 1968-70, large amounts of germplasm were obtained from various parts of the world and tested. Particular emphasis was placed on obtaining new sources of white-grain germplasm—the preferred type in NWFP. After preliminary observations and testing, the superior fractions of this material were crossed with the best local materials and tested in different agroecological zones. By the early 1970s, a new generation of improved OPVs had been developed, tested, and released for general use. The new genotypes had high yield potential and a temperate-zone type of plant architecture. All were superior to J-1 in yield potential and resistance to leaf blights.

From 1968 to 1971, West Pakistan's maize research infrastructure was expanded and strengthened through the Ford Foundation project. The Yousafwala research station was upgraded in 1968 to the status of the Maize and Millets Research Institute (MMRI) for the Province of West Pakistan, and plans were formulated to make the Pirsabak seed farm the main maize research station for NWFP.

Maize Research under the Federal Republic

After the separation of Bangladesh in 1971, a general period of drift ensued in the nation's agricultural research apparatus. The lack of a coordination mechanism for research had led to increasing fragmentation of national efforts (Albrecht et al., 1979). West Pakistan became a federal republic comprising four provinces. Since agricultural research and extension were considered largely provincial responsibilities, the former Agricultural Research Service (ARS) of West Pakistan was disbanded and replaced by four provincial systems.

This left few maize research staff in NWFP (most maize researchers were from the Punjab and returned there after the ARS was disbanded) and an underdeveloped research infrastructure. Priority was therefore given to strengthening the maize research capacity in NWFP. In 1971, plans were finalized to develop a new Maize and Millets Research Institute for NWFP at Pirsabak, Nowshera. Meanwhile, MMRI at Yousafwala was made part of the Punjab Province's Agricultural Research Institute (today called AARI), and Dr. A.R. Chaudhry became its new director, a position he held from 1971 to 1979.

The Agricultural Research Council of Pakistan—Another post-separation undertaking was the establishment of an Agricultural Research Council (ARC), which was to operate along the lines of the former colonial Imperial Council for Agricultural Research of British India (Amir, 1982). USAID provided a major agricultural development grant to Pakistan to help establish this body, and in 1974, ARC was formally launched under the chairmanship of Malik Khuda Baksh Bucha, the former provincial and federal Secretary and Minister of Agriculture. During Bucha's administration, land was obtained to build NARC's headquarters near Islamabad and various nationally coordinated research programs—including the National Coordinated Maize, Sorghum, and Millets Program—were started for the major crops and agricultural commodities.

The ARC viewed its National Coordinated Research Programs as the primary conduit for funding and coordinating the research activities of provincial and federal research institutes and the agricultural universities. According to Dr. Amir Muhammed, "the philosophy behind such programs lies in a coordinated attack on national problems through cooperative planning and coordinated resource allocation" (Amir, 1982).

One of the first priorities of the ARC in maize was to speed up the transfer of superior varieties and higher-yielding production technologies to Pakistani farmers. The Ford Foundation had helped Pakistan launch its crop management research program for maize in the early 1970s. In 1972, Dr. A.F.E. Palmer, a CIMMYT production agronomist, took up a post in Pakistan, where he worked closely with Dr. F. Karim and other NWFP maize researchers to establish an on-farm research program.

By 1973, a set of production practices called "POPs" (Package of Practices) had been developed to go along with the higher yielding varieties. The POPs recommended fertilizer application rates of 60 kg/ha of N and 30 kg/ha of P, line sowing and other cultural practices for improved weed control (instead of the prevailing practice of broadcasting seed), and seeding rates of 60,000 plants per ha to optimize grain production rather than total dry matter production.

With a supposedly superior technology in hand, the provincial "Maize Action Plan" was launched in NWFP in 1974. It called for close collaboration between the research and extension services in placing over 600 "diamond" half-acre demonstration plots on farmers' fields. These demonstrations, also referred to as 2 x 2 demonstrations, had four treatments: 1) farmer variety and production practices; 2) farmer variety and the recommended POP; 3) improved variety and farmer production practices; and 4) improved variety and the recommended POP.

Considerable effort was also devoted to seed multiplication and distribution. Using the basic seed of recommended OPVs increased at the Pirsabak station, over 450 half-acre seed multiplication plots were planted on farmers' fields in many of the maize-growing areas of NWFP. The strategy was to encourage farmer-to-farmer seed distribution and blanket the province with improved varieties.

Research and extension efforts to promote on-farm seed production and farmer-to-farmer distribution resulted in the dissemination of improved varieties. Nitrogen fertilizers were also adopted by many farmers. Unfortunately, no sustained and organized seed production and distribution system was institutionalized to provide maize farmers with a continuing flow of quality seed. Moreover, other than the adoption of nitrogenous fertilizer, little of the package of production practices was adopted (Ashraf and Winkelmann, 1976).

Despite the failure to adopt some of the recommended practices, their appropriateness was never really questioned. Rather, a nationwide campaign was planned to extend the same package of practices in the Punjab (Izuno, 1974). The 1976 National Maize Production Plan called for the introduction of improved OPVs at the farm level and promotion of the package of improved practices (ARC, 1976).

The plan went into effect with much fanfare in the 1976 kharif season. As in the case of the previous research-extension campaigns, it met with initial success. Through the use of improved varieties and fertilizers, national maize production rose 15% the first year. But, as in the past, other components of the recommended package of practices were generally not taken up by the farmer, and no sustained system of seed production and distribution was established to provide farmers with a continuing flow of improved seed.

The PARC Period—In 1978, the Agricultural Research Council was reorganized and given a new masthead, the Pakistan Agricultural Research Council (PARC), with Dr. Amir Muhammed as chairman. During the past decade, the role of PARC has expanded greatly, even though provincial institutions and universities still carry out the bulk of the agricultural research in Pakistan.

International donor assistance for agricultural research in Pakistan has increased significantly during the PARC period. In 1986-87, the World Bank, USAID, UNDP/FAO, CIDA and IDRC (Canada), ADB and ADAB (Australia), and the Swiss and Italian governments were also funding PARC projects. CIMMYT's maize collaboration in Pakistan is funded under the USAID ''Management of Agricultural Research and Technology'' (MART) project.

A major PARC priority during the past 10 years has been to develop the National Agricultural Research Center (NARC). A talented research staff has been assembled and extensive facilities—including laboratory and field experimentation units, a reference library and scientific information center on agriculture, a computerized data processing facility, and a training center—have been constructed.

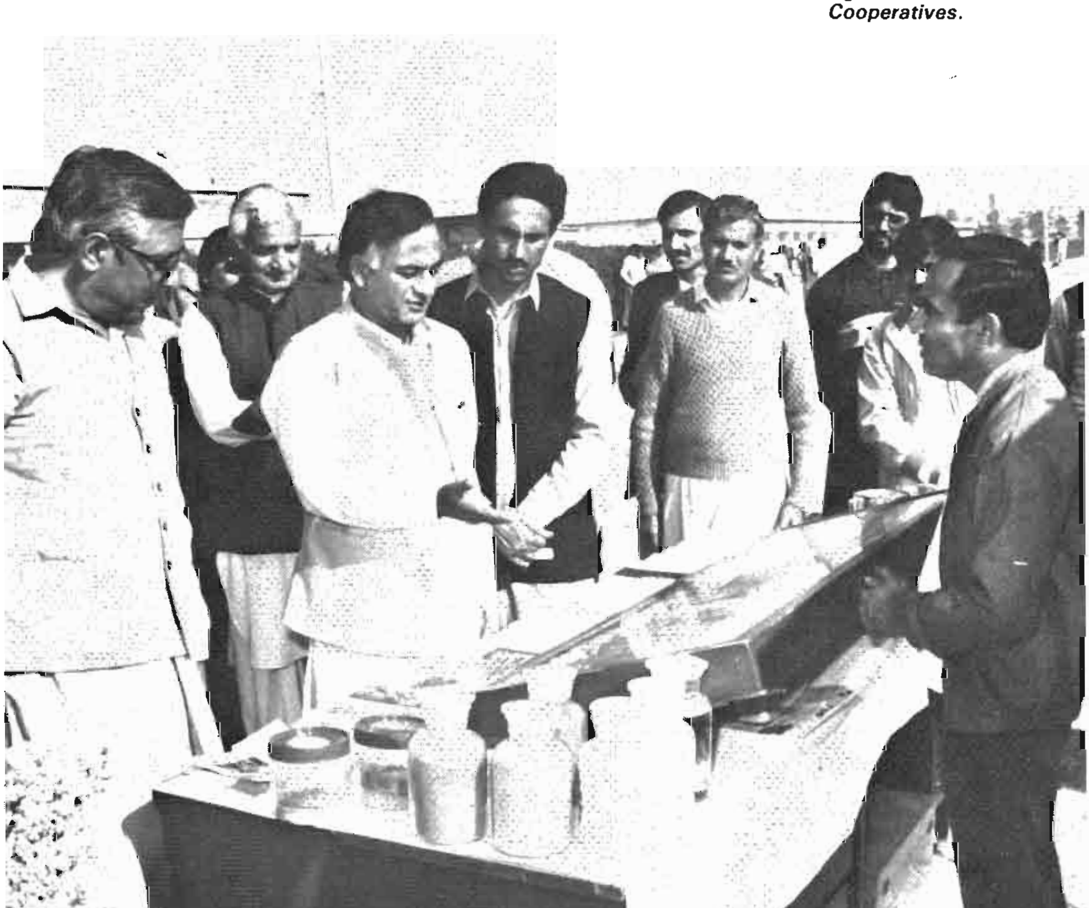
NARC's goal is ''to conduct research in areas of national importance where such research is not currently being undertaken or is seriously inadequate.'' (Amir, 1982). Moreover, NARC was to be a catalyst in improving the process of technology transfer in Pakistan. In the words of Dr. Muhammed, ''A major emphasis in NARC research will be the farming systems approach where the production technology available for various agricultural commodities will be synthesized into an integrated system suitable for different agroecological regions and socioeconomic groups'' (Amir, 1982).

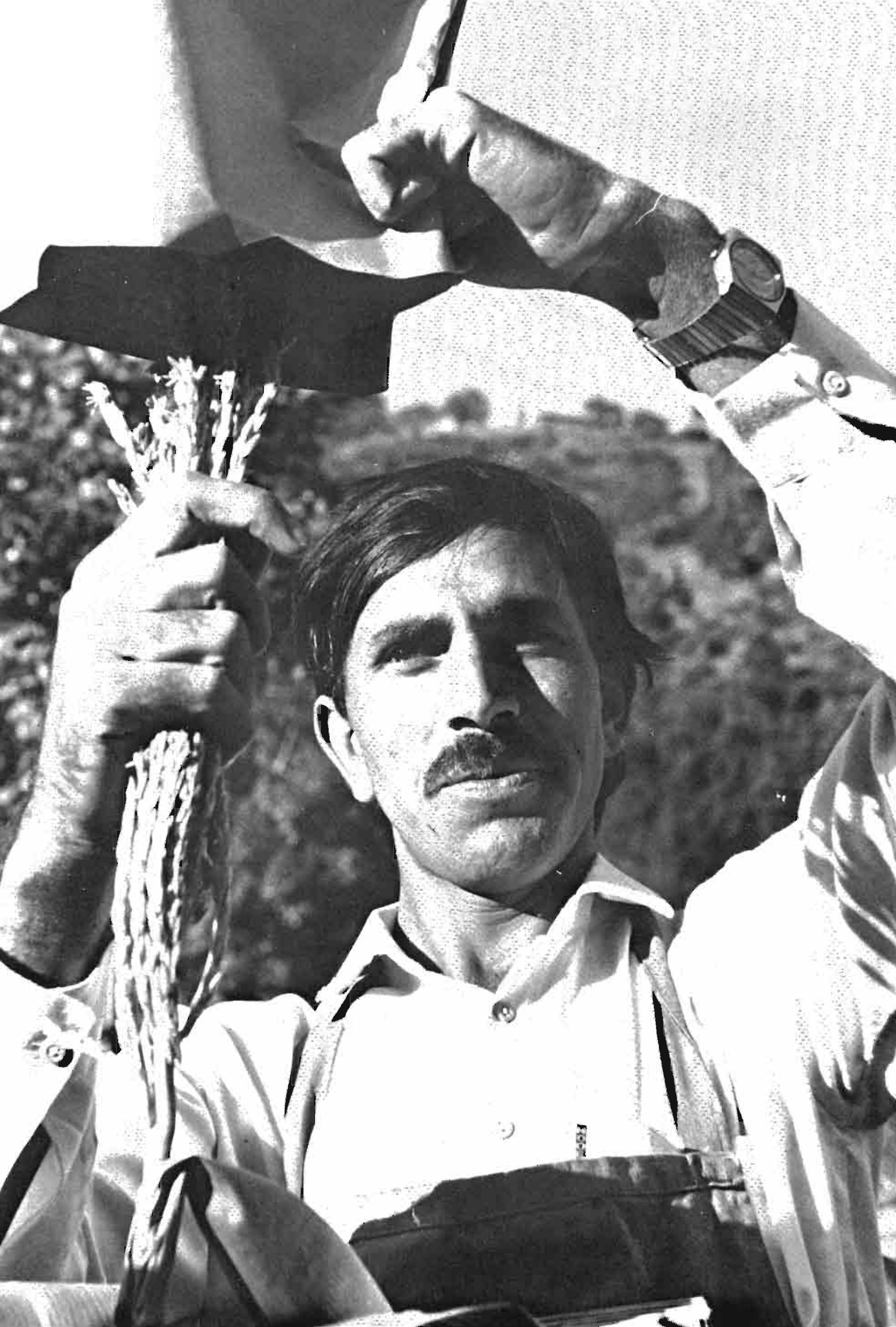
Increasingly, PARC's on-farm research activities have taken on an interdisciplinary approach in which biological and social scientists work together to diagnose the production constraints of farmers and to identify the best opportunities for research impact. In 1985, PARC established Agricultural Economics Research Units (AERUs) comprised of agricultural economists who work on issues related to technology generation and verification. AERUs have been established at NARC, Tarnab, Faisalabad, Tando Jam, and Quetta.

Other PARC programs are also addressing on-farm research issues, especially the USAID-supported Management of Agricultural Research and Technology (MART) project which is providing agricultural management assistance to federal and provincial institutions, and the CIDA-supported Barani Agricultural Research and Development (BARD) project, which is providing additional research support for food crop production in rainfed areas

Finally, as part of its efforts to strengthen the linkages between "technology generation" and "technology transfer" institutions, PARC also established a Crop Maximization Program (CMP) in 1985, with financial assistance from the Italian government. The CMP has concentrated on demonstrating improved technology for three commodities: wheat, rice and maize.

An important function of the National Coordinating Maize Program, NARC, is to display the achievements of Pakistani maize scientists. Here Dr. Muhammad Aslam, National Maize Coordinator, describes maize varieties developed for various growing environments to Dr. Amir Muhammed, Chairman, PARC, and to Mr. Rao Sckander Iqbal, Federal Minister for Food, Agriculture, and Cooperatives.





The National Maize Research System

During the past 20 years, maize research programs have been strengthened at the provincial and federal level (Wahid, 1982). The research infrastructure at the principal maize experiment stations has been improved through the construction of offices, laboratories, staff housing, and seed storage facilities and the development of research plots with irrigation for field experimentation. Today, viable maize research stations are in place in Yousafwala, Pirsabak and NARC.

More than 70 researchers in public institutions are directly engaged in maize research, and a similar number probably participate in disciplinary research related to maize production. Over the past two decades, the professional qualifications of Pakistani maize researchers have improved. In 1987, most maize scientists had at least MSc degrees and more than a dozen individuals had either received PhD degrees or were enrolled in PhD programs. More than 60 Pakistani researchers were also alumni of CIMMYT's in-service training courses and/or its visiting scientist program.

In the mixed federal-provincial research system, MMRI and CCRI are mandated to develop improved technologies and production practices for the farmers in their provinces, while NARC's maize research program is involved in germplasm development and crop management research for rainfed areas in the Islamabad Capital Territory, northern Punjab, and southeastern NWFP.

National Coordinated Maize Program

The National Coordinated Maize, Sorghum, and Millets Program (NCMP) officially began operation in 1975, with Dr. A.R. Chaudhry at MMRI, Yousafwala, as the first coordinator. In 1977 Dr. Mohammad Qasim Chatha, formerly a maize researcher at MMRI, Yousafwala, joined ARC and was appointed NCMP Coordinator, a position he held for 10 years. In 1987 a new Coordinator, Dr. M. Aslam, was appointed after Dr. M. Chatha assumed leadership for PARC's Crop Maximization Program. The sorghum and millet portion of the NCMP was separated and a new nationally coordinated crop program was established for these crops.

The following organizations currently participate in the NCMP: the NARC Maize Program; CCRI, Pirsabak; MMRI, Yousafwala; and the Mona Reclamation Project in Punjab. Unofficially, the Department of Agriculture of AJK also participates in the NCMP.

The NCMP coordinates PARC's financial support to the provincial maize research programs, including funds for additional staff positions, equipment, vehicles, and scientific literature (Chatha and Rehman, 1981). The NCMP also provides several services (described below) to the participating member organizations.

National Uniform Maize Yield Trials—These trials are conducted at various sites on and off research stations throughout the maize growing areas of the country. Two trials are distributed annually: one with short-season materials and the other with full-season materials. Entries in these trials are submitted by the nation's maize research programs and include the best advanced materials currently available in the country. NARC handles the preparation, distribution and data analysis of these trials.

Workshops and Meetings—Each year, the NCMP hosts travelling workshops designed to allow maize scientists from different research institutions to review the work of cooperating institutes and conducts a planning meeting to chart future NCMP activities. These workshops usually last for a week and are organized so that scientists can also observe the maize crop in farmers' fields as well as in research plots. The meetings have helped to build a spirit of collaboration between provincial and federal groups involved in maize research.

Liaison with Maize Research outside Pakistan—As a service to the participating institutions, the NCMP coordinates the distribution of international trials requested from CIMMYT, the International Institute of Tropical Agriculture (IITA), Nigeria, and other maize research organizations abroad. The coordinator represents the NCMP at international meetings and in official correspondence with other national maize research institutions. Finally, the activities of CIMMYT's resident maize advisor at the provincial and national level were planned and supported through the NCMP.

Training Support in Maize—The NCMP is responsible for nomination of scientists for training abroad and for short-term training courses at CIMMYT and elsewhere. It also organizes in-country training activities to support the continuing education needs of maize researchers from the participating institutions.

NARC's Maize Program

Currently, NARC's Maize Program is under the direction of Dr. M. Aslam, who also serves as Coordinator for the NCMP. This program has two major research components: breeding materials for higher elevations and barani drought-prone conditions, and on-farm research directed at the problems of rainfed (barani) maize production NARC has also released several improved OPVs including Gauher (derived from Pirsabak 7930) for rainfed areas and Kashmir Gold (derived from Yousafwala 7845, selected at MMRI from CIMMYT Population 45) which is used in AJK.

Breeding work is presently focusing on two populations: Pool-10, a very early-maturing yellow population, and Pool-20, an intermediate maturity white population These populations are being improved for stalk rot and leaf blight resistance and for general stress tolerance. In 1986 a program was initiated to develop cold-tolerant germplasm sources for the higher elevations. The on-farm research program is primarily concerned with formulating recommendations to increase the productivity of the very low-yielding rainfed maize areas of the agroecological zone in which Islamabad is situated

The National Coordinated Maize Program (NCMP) manages PARC's financial support to federal and provincial institutions engaged in maize research by providing such research support services as the operation of national yield trials, sponsorship of workshops and field trips, liaison with other national and international maize research institutions, and support to individual scientists for in-service and degree training in Pakistan and abroad.

The NARC Maize Program performs a number of service activities to support the NCMP. Among the most important of these is the preparation of the National Cooperative Maize Yield Trial (NCMYT). The NARC Maize Program staff prepare and distribute the trial, as well as processing and analyzing the resulting data. The NCMYT is grown annually by participating institutions in the NCMP and includes their most advanced varieties and hybrids. The results of the 1986 kharif NCMYT at selected locations is shown in Table 12.

Table 12. Results at Selected Sites of the NCMYT, Kharif 1986

Entry	Danna	NARC	Y'wala	F'abad	Swat	Mansehra	Average
	Yield, kg/ha						
YH-3	8,620	4,133	3,764	4,026	4,671	3,886	4,850
EV-6081	7,606	4,058	3,921	3,563	5,833	6,438	5,237
EV-1081	6,112	3,156	4,094	3,825	5,097	3,846	4,355
K. Gold	8,687	4,002	4,211	3,755	5,780	3,761	5,033
EV-5081	7,284	4,469	3,774	4,805	4,979	5,390	5,117
Azam	—	3,805	4,373	4,242	6,768	4,426	4,773
Gauher	7,154	4,667	3,147	4,050	6,148	4,308	4,912
Eshan	8,335	3,487	4,322	5,200	5,871	5,050	5,378

Source: PARC National Coordinated Maize Program 1987

Maize Research in NWFP

Maize research in NWFP is conducted at CCRI—now part of the integrated NWFP Agricultural University system. Maize research at CCRI was under the direction of Dr. Khan Bahadur during the 1970s, with assistance from Dr. M. Saleem and Dr. M. Aslam. Currently, Dr. M. Saleem is in charge of maize research at CCRI. While plant breeding is the primary research thrust, a program of on-farm research is also conducted in the NWFP districts of Swat, Mardan and Manserha, and some 16 agricultural research officers are currently engaged in maize breeding and crop management research projects there.

CCRI has released a number of new OPVs during the past decade (Table 13). In particular, the variety Azam has been popular with farmers in various low- and intermediate-elevation production areas (PARC, 1987; Khan et al., 1986; Byerlee et al., 1987). Changez, a mid-season, white-grain variety was developed from crosses between the most widely grown local white flint-grain material, Swabi white, and U.S. yellow inbred lines including

WF9, M14, B37, WM13R, HY, A619, Oh45, and others. This variety, however, lacks sufficient resistance to leaf blights. Zia, an intermediate maturity, white-grain variety, was developed from the cross, (Early King x Payette) x Changez. (Early King is a selection made in South Africa from the U.S. variety, Hickory King, while Payette is a short-season variety from Canada.) Shaheen, the earliest maturing white-grain variety, was developed from a cross between Zia and a very early maize based on three U.S. varieties: Nodak and Mandan, and Payette. The full-season, white-grain variety, Khyber, was the result of a cross of the yellow-grain variety, Akbar, developed at Yousafwala, and Bowman's Cole Creek, a white dent variety from Kansas in the USA.

Table 13. Improved Open-Pollinated Varieties Released in NWFP, 1970-86

Variety	Release	Description	Days to maturity*
Changez	1970	White flint	85- 90
Zia	1971	White flint-dent	100-115
Khyber	1974	White dent-flint	110-120
Shaheen	1974	White flint	80- 90
Sarhad White	1976	White dent-flint	110-120
Sarhad Yellow	1976	Yellow dent-flint	110-120
Azam	1983	White dent-flint	90-100
Ehsan	1984	White flint	95-100

* At CCRI, Pirsabak

Source: PARC National Coordinated Maize Program 1987

Several pools (populations) are currently undergoing improvement to serve as germplasm sources for new OPVs and for inbred line development to make hybrids. Pool-20, a new version of the population that produced Shaheen, is a white-grain material with early maturity (85-90 days at Pirsabak). Pool-20 was developed from the original Shaheen population whose parentage was described previously. In 1979, a new material, Pioneer Hybrid Composite (bulk of F2 seed of early maturing hybrids from Pioneer Hi-Bred International, USA), was introgressed into Pool-20. This material is suitable in maturity for the mid- to high-elevation areas of NWFP. However, it lacks the cold tolerance of the original Shaheen population and is susceptible to several leaf blights. To develop cold tolerance, Shaheen is being planted in the high elevations (Kaghan, Kalam) during the kharif season and in the rabi season at Pirsabak, where cold temperatures are common. An alternative approach for the improvement of disease resistance in New Shaheen is also being followed (CCRI, 1986). Pool-20 has been crossed to Pirsabak 7930 to combine the disease resistance of this variety with the earliness of Shaheen. The cross Pirsabak 7930 x Shaheen greatly outyielded the old Shaheen but retained its earliness in trials conducted in 1986 (Table 14).

The success of the variety, Azam, which was developed from the cross, (Pirsabak 7930 x Zia) x Pirsabak 7930, led to the formation of Pool-40. Pool-40 is an intermediate-maturity (90-95 days at Pirsabak), white-grain population. It is being improved for resistance to leaf blights (*Helminthosporium* spp.) and earliness. A recent cross derived from this material, Pirsabak 7930 x Azam, has outyielded all other genotypes during recent yield tests (Table 14).

Table 14. Short-Season NCMYT Results, Pirsabak, Kharif 1986

Entry	Yield kg/ha	Days to 50% silk	Stalk rot, %	H. maydis 1-5 scale
Pirsabak 7930 x Azam	7,800	51	3	2
Azam	7,306	51	10	2
Shaheen x Azam	6,786	49	16	3
Single cross	6,453	47	9	3
Pioneer Hybrid Comp.	4,867	50	23	4
Shaheen	3,173	49	26	4
LSD 5%	1,101			
C.V	12.0%			

Source CCRI 1986 Annual Report

Pool-60 is a late-maturing (105-110 days at Pirsabak) white-grain population which has been managed as two separate populations: Pool-60A was developed by crossing Sarhad White x Pirsabak 7734 and Pool-60B was developed by crossing Sarhad Yellow x Lote 81 (Compuesto Seleccion Precoz). These two populations are now being merged into one. The variety Eshan (100-day maturity) was developed from Pool-60; it was a top-yielding entry in the NCMYT during 1985-86 and shows improved resistance to stalk rot and leaf blights compared with previous varieties such as Sarhad White Ehsan also combines well with inbred lines developed from Sarhad.

Although the development of open-pollinated varieties continues to receive the most attention, CCRI's maize program is also developing white hybrid materials. Inbred lines at S6 stage have been developed from Pool-60 and Pool-40. The most promising double top-cross hybrid developed to date is a cross of (Pirsabak 49 x Pirsabak 2) x Ehsan This hybrid is intended for commercial release As yet, no outstanding inbred lines have been developed from Pool-40

An active program of maize research is conducted at the Cereal Crops Research Institute (CCRI)—now part of the integrated NWFP Agricultural System. Currently led by Dr. M. Saleem, the CCRI maize program has released a number of high-yielding open-pollinated varieties for the lower and intermediate elevations of the province. Breeding programs give emphasis to the development of open-pollinated varieties. CCRI has also conducted a considerable amount of on-farm research in the province.

The CCRI program has been actively involved with the international maize testing program coordinated by CIMMYT. It has regularly evaluated the 250 best families in several of CIMMYT's populations and has developed some outstanding experimental varieties through this work. Pirsabak 7930 (from Population 30—Blanco Cristalino-2) was developed through the international progeny testing system coordinated by CIMMYT. It has been an outstanding genotype in Pakistan, where it was used to develop Azam, and has also been released as a commercial variety in Benin, Togo and Zambia.

In addition, CCRI receives Experimental Variety Trials (EVTs) from CIMMYT containing superior experimental varieties developed by other national programs that participate in the IPTT system. Each EVT includes materials with the same grain color and similar climatic adaptation and is tested at 30 to 40 locations worldwide. Table 15 shows the results of one of these trials, EVT 16B, tested at Pirsabak in kharif 1986.

Table 15. Results of CIMMYT Experimental Variety Trial 16B, Pirsabak, Kharif 1986

Entry	Yield kg/ha	% best check	Days to 50% silk	Stalk rot %	H.maydis 1-5 scale
Gemeiza 8444	7,819	111	61	4.2	1.3
Across 7844 RE	7,710	109	65	1.0	1.5
Chitedze 8444	7,627	108	62	1.5	1.3
Babungo (1) 8334	7,080	100	63	1.8	1.3
Across 7734 RE	7,024	100	62	0.6	2.0
Lambo 8342	6,883	98	64	0.0	1.3
Tlaltizapan 8444	6,863	97	60	4.2	1.0
Gemeiza (1) 8444	6,579	93	65	2.8	1.8
Across 8334	6,485	92	61	2.7	1.0
Iboperenda 8342	6,386	91	57	2.1	1.8
Across 8342	6,151	87	58	7.2	1.9
Chitedze 8244	6,022	85	59	0.0	1.0
Checks					
Azam	7,052	—	56	0.6	1.5
Eshan	6,915	99	59	1.8	2.3
LSD 5%	1,496				
C.V	15.2%				

Source: 1986 Preliminary Report, CIMMYT International Maize Testing Program

Since the early 1970s, CCRI has also conducted a program of on-farm research in collaboration with CIMMYT staff. The work of Mr. Kiramat Khan, a research officer in Swat Valley, has been especially noteworthy. On the basis of previous on-farm surveys and experiments, Khan planned a series of 12 verification trials that were to be completely managed by participating farmers. In these trials, three improved technological components were evaluated: 1) the recommended variety, Azam, 2) greater use of phosphorus, and 3) the yield advantage of early thinning (target 65,000 plants/ha at three weeks after emergence).

The results provided important feedback to researchers (Khan et al., 1986). The only treatment that gave a consistent response was the improved variety, Azam, which yielded 600-800 kg/ha more than the farmers' variety. No other obvious advantage was observed in the other recommended practices over the farmers' own practices. In the case of this study, the high payoff in making improved seed available was again documented.

Maize Research in the Punjab

In Punjab, maize research is conducted by MMRI, Yousafwala, which is part of the Ayub Agricultural Research Institute (AARI). Since 1979, MMRI has been under the direction of Dr. M. Afzal. It has a professional maize research staff of 17, most of whom are located at the institute's headquarters in Yousafwala. Sub-station programs are also operated at Faisalabad, Rawalpindi and Sargodha. MMRI's primary research activity is breeding. Some on-farm experiments—micro-plot varietal and simple agronomic trials—are also conducted, both from MMRI headquarters in Yousafwala and from the sub-station programs at Faisalabad and elsewhere in the province. Maize is also being researched as a fodder crop at the Fodder and Forage Research Institute, Sargodha, Punjab.

During the late 1960s and early 1970s, several high-yielding maize varieties were released in Punjab Province. Neelum, a full-season, yellow semi-dent material, was developed using local Pakistani varieties, together with germplasm from Latin America and the U.S. corn belt. Akbar, a full-season yellow semi-dent, was developed from a cross between Neelum and corn belt material. Agaiti-72, a short-season, yellow dent was developed from a six-way cross of (M14 x Pa32) x (WF9 x W9) with (A495 x A556). In addition, Sadaf, a white semi-dent version of Neelum, was also released in 1975 for use in the Punjab. (By this time, however, maize farmers in central Punjab had switched primarily to growing yellow-grain genotypes, largely due the widespread introduction of J-1 a decade before.)

Since 1975, two new OPVs have been released by the provincial government (Table 16). Sultan—a full-season, yellow dent selected from crosses between Akbar, Syn 548, Syn 547, Neelum, and Comp. II. Sunerhi (an early-season, yellow dent)—was based on Agaiti-72 and CIMMYT's Population 31, an intermediate-to-early, yellow-dent material. These newer genotypes have more subtropical and tropical germplasm in their pedigrees than predecessor varieties such as Akbar and Agaiti-72. With the increasing severity in the 1980s of leaf blight diseases caused by *Helminthosporium* spp. and stalk rots caused by *Fusarium* spp., even greater amounts of tropical and subtropical germplasm have been introgressed into MMRI's germplasm complexes.

Table 16. Improved Open-Pollinated Varieties Released in Punjab Province, 1970-86

Variety	Release	Description	Days to maturity*
Neelum	1970	Yellow dent-flint	100-110
Agaiti-72	1972	Yellow dent-flint	80- 90
Akbar	1973	Yellow dent-flint	100-110
Sadaf	1975	White dent-flint	100-110
Sultan	1984	Yellow dent	100-110
Sunerhi	1984	Yellow dent	90-100

* At MMRI, Yousafwala

Source: Unpublished data, PARC National Coordinated Maize Program

Today, three gene pools are being maintained and improved at MMRI, Yousafwala (MMRI, 1987). Pool-10, a short-season, yellow-grain population, is comprised of Sunerhi crossed to a bulk from CIMMYT Pool 17. Two experimental varieties have been derived from Pool-10: EV 1081 and EV 1085. The former variety has been submitted to the Variety Release Committee for registration and official release for commercial production in Punjab Province.

Pool-50, a full-season, yellow-grain population, was originally based on the variety Sultan. In 1982, this pool was crossed with the experimental variety, Tocumen 7931, developed from

CIMMYT's Population 31 (Amarillo Cristalino-2). Two experimental varieties have been developed from this germplasm complex. EV 5081, developed in 1981 when the Pool was based only on Sultan; and EV 5085, developed in 1985 and based on the Sultan x Tocumen 7931 cross. EV 5085 has been submitted to the Variety Evaluation Committee for registration and official release for commercial production. In 1986, four new experimental varieties were incorporated into Pool-50: La Molina 8128 and Across 7728, both from CIMMYT Population 28 (Amarillo Dentado), Poza Rica 8136 from CIMMYT Population 36 (Cogollero); and Across 8024 from CIMMYT Population 24 (Antigua-Veracruz 181).

Maize research in the Punjab is conducted primarily by the Maize and Millets Research Institute (MMRI), Yousafwala, which is part of the Ayub Agricultural Research Institute (AARI) system. Now under the direction of Dr. M. Afzal, MMRI has released more than a half-dozen improved open-pollinated maize varieties for use in Punjab, especially in the irrigated areas of the Punjab plains.

Pool-60, a full-season, white semi-dent, was developed using Composite 15, made up of the varieties Changez, Sadaf White, and Khyber. In 1982, Pool-60 was crossed with an experimental variety, Pirsabak 7930, based on CIMMYT's Population 30 (Blanco Cristalino-2), a tropical white, semiflint material with early maturity and shortened plant height. Two varieties developed from Pool-60, EV 6081 and EV 6085, have been submitted to the Variety Evaluation Committee for registration and official release for commercial production.

Yields of some of the recent experimental varieties developed from Pools 50 and 60 are shown in Table 17. Progress has been achieved in yield potential in the newer materials as compared with the check varieties. However, the best material is a white-grain variety which has little applicability in the main maize-growing areas of Punjab today, where yellow grain is preferred. A hybrid development program is also underway at MMRI using U.S. corn belt inbred lines such as Mo17, B73, and B84, older local inbred lines such as Punjab 7, and new inbred lines being extracted from Pools 10, 50, and 60, as well as Sultan and Sunehri.

Table 17. Microplot Yield Trial Results, Full-Season Varieties, Kharif 1986, Yousafwala

Entry	Yield kg/ha	% Best check	Days 50% silk	Stalk rot %	H.maydis 1-5 scale
EV-6081 (W)	5,251	123	55	2	2
EV-5081 (Y)	4,693	110	51	13	3
Sultan (Y)	4,587	107	54	5	3
Checks					
Sadaf (W)	4,277	—	53	9	4
Akbar (Y)	3,557	—	54	7	4
LSD 5%	679				
C.V	10 1%				

Source MMRI Annual Report 1986

International progeny testing and experimental variety trials from CIMMYT are regularly received and screened at MMRI for useful germplasm. More recently, tropical hybrid trials and inbred lines have been received from IITA in Nigeria and the Yugoslavian National Maize Program. (Pool-60 is being crossed with TZ inbred lines from IITA.) CIMMYT, with the recent establishment of its hybrid program, is also furnishing inbred lines for evaluation. In general, a wealth of useful germplasm has been provided to MMRI's maize improvement program, especially by U.S. maize programs and CIMMYT.

For many years, MMRI has been an active participant in CIMMYT's international testing program. It has developed a number of experimental varieties from the IPTTs since 1974. Kashmir Gold, popular in AJK and in other countries, is derived from Yousafwala 7845 from IPTT 45 (Amarillo Bajio). Experimental varieties developed at MMRI are later tested internationally through CIMMYT EVTs. The results of a recent trial, EVT 16A, are shown in Table 18.

Private Sector Maize Research

At present, most maize research in Pakistan is conducted by public sector institutions, although private sector interest in maize research and seed production is increasing.

Table 18. Results of CIMMYT Experimental Variety Trial 16A, at MMRI, Yousafwala, Kharif 1986

Entry	Yield kg/ha	% Best check	Days 50% silk	Stalk rot %
Ludhiana 8445	6,889	126	54	8.7
Across 7845 RE	6,294	115	54	9.2
Sids 8445	6,269	115	51	11.4
Tlaltizapan 8445	6,256	114	53	20.9
Antalya 8445	5,772	105	53	15.6
Antalya (1) 8445	5,757	105	51	13.5
Hyderabad 8245	5,726	105	53	9.7
Across 7748 RE	4,572	84	51	37.5
El Paso 8448	4,564	83	49	30.4
Tlaltizapan 8448	4,469	82	49	24.7
Antalya 8448	4,357	74	48	28.7
Pirsabak (2) 8248	4,070	71	48	30.6
Antalya (1) 8448	3,891	71	50	28.9
Checks				
EV 1081	5,473	—	53	16.6
Sunehri	4,669	86	46	16.3
LSD 5%	820			
C.V	10.9%			

Source: 1986 Preliminary Report, CIMMYT International Maize Testing Program

Rafhan Maize Products, Ltd., operates the most notable private sector maize research effort in Pakistan. The wet-milling company runs a small but highly effective hybrid maize breeding and seed production program. Rafhan provides its contract growers with hybrid maize seed, fertilizer, and other inputs on credit and receives their entire maize harvest. Led by Dr. Khan Bahadur, Rafhan's small maize research and production staff conduct a hybrid breeding program, produce hybrid seed, and supervise the crop management activities of 300 growers and 15,000 ha of maize land.

The most notable private sector maize research effort to date has been that of Rafhan Maize Products Ltd. To help assure a more reliable supply of maize grain for its wet-milling operations in Faisalabad, Rafhan in 1969 decided to undertake a large-scale maize production program using contract growers. In 1970, Dr. A.G. Bhatti became the leader of this integrated maize research and production program. Since 1980, the program has been under the direction of Dr. Khan Bahadur.

Under the Rafhan production scheme, contract growers are given interest-free loans to purchase high quality hybrid maize seed, pesticides and fertilizers. Technical assistance in using these inputs is provided through the field agronomists who supervise the contract growers. Because the hybrids are based on U.S. corn belt materials and lack resistance to leaf blights, contracts are primarily given for spring season maize production, a period of low disease incidence.

To supply the hybrids, a modest research program was initiated drawing on U.S. public inbred lines such as Mo17 (Missouri), B73 (Iowa), A619 (Minnesota recovery from Oh42), H-51 (Indiana) and Lines 32 and 2001 (Funk Brothers). These U.S. inbred lines were crossed with older inbred lines from Pakistan (Punjab 7) and new inbreds derived from Sarhad Yellow and other populations developed by the public sector. Rafhan has developed the technical knowledge to maintain these inbred lines and to exploit favorable heterotic patterns in local materials. In 15 years, 12 different types of hybrid have been produced, including genotypes for normal, waxy and popcorn grain production. The first hybrids were varietal and top crosses. Today, a generation of single crosses has been developed for future introduction.

Rafhan's handful of maize staff (breeders, agronomists and seed production specialists) operate a breeding program to develop new hybrids, produce 500-600 tons of hybrid seed each year, and supervise 10-15,000 ha of maize land managed by 200-300 growers. In this system, 30,000 to 45,000 tons of maize are produced by the contract growers each year, with an average yield of nearly 3 t/ha for the group as a whole—nearly three times the national average yield.

Dr. Khan Bahadur, Manager of Rafhan's successful maize research and production program, attributes his organization's success to four factors: 1) well-defined goals and production targets; 2) human talent and financial resources capable of meeting program objectives; 3) a staff who are given the mobility, responsibility, and authority to fulfill their job descriptions; and 4) a compensation policy that rewards performance in meeting assigned objectives.

Cargill, a U.S. grain and seed company, recently established seed programs for maize, sunflower and sorghum-sudan grass. However, no maize hybrids had been released by the company until 1989, when it put 400 tons of hybrid maize seed on the market after evaluating several candidate varieties in provincial and national yield trials to assess their suitability for Pakistan.

Other private seed companies—including Dekalb-Pfizer Genetics and Pioneer Hi-Bred International—have been exploring the possibility of establishing seed programs in Pakistan, either independently or in association with Pakistani companies.

CIMMYT's Maize Research Collaboration

CIMMYT has had a close working relationship with Pakistani maize programs and scientists for more than 20 years. Between 1968 and 1976, CIMMYT's collaboration with Pakistani maize research institutions was financed by the Ford Foundation through several grants. These grants also provided funds for operational research activities, in-service training, vehicle and equipment purchases, and CIMMYT's resident maize advisors in Pakistan.

Since 1976, CIMMYT's collaboration with Pakistan on maize has been financed through several institution-building grants provided by USAID to PARC, covering the periods 1976-84 and 1984-87. In both grant periods, PARC contracted with CIMMYT to help strengthen the adaptive maize research capabilities at NARC and the provincial institutions participating in the NCMP.

During the 20-year period of collaboration with Pakistani maize research institutions, CIMMYT's Maize Program has been under the direction of Dr. John Lonnquist (1967-70), Dr. Ernest Sprague (1971-83), and Dr. Ronald Cantrell, (1984-present). In addition, Dr. R.L. Paliwal has served as Associate Director of the Maize Program since 1975. CIMMYT has also posted five resident maize scientists to Pakistan between 1968 and 1987.

The following is a brief description of the products and services that have been provided through CIMMYT's maize research collaboration with Pakistani institutions.

Germplasm Development

CIMMYT's maize improvement program involves the creation of new germplasm development pools, population improvement, multilocational progeny testing, and the development of experimental OPVs. It was designed to function in partnership with national programs and comprises three types of international trials: International Progeny Testing Trials (IPTTs), Experimental Variety Trials (EVTs), and Elite Experimental Variety Trials (ELVTs).

Pakistani maize research institutions have been active participants in the international testing program, especially the IPTT system (Table 19). Through access to CIMMYT's broad range of genetic resources, national maize research institutions have been able to 1) identify superior varieties from adapted CIMMYT populations, 2) develop new germplasm complexes and 3) enrich existing national gene pools and populations with new germplasm sources.

CIMMYT's intermediate and short-season tropical and subtropical populations have been especially useful in Pakistan. They possess good yield potential and have given Pakistan's breeding materials

Table 19. International Progeny Testing Trials Evaluated in Pakistan, 1974-86

No.	Population	Grain color	Pir-sabak	Yousaf-wala	Islam-abad
Tropical Materials					
23	Blanco Cristalino-1	White	x		
24	Antigua-Veracruz 181	Yellow		x	
25	Blanco Cristalino-3	White	x		
26	Mezcla Amarillo	Yellow		x	
28	Amarillo Dentado	Yellow		x	
30	Blanco Cristalino-2	White	x		
31	Amarillo Cristalino	Yellow		x	x
32	ETO Blanco	White	x		
35	Antigua-Rep. Dom.	Yellow			x
49	Blanco Dentado-2	White	x		
Subtropical Materials					
33	Amarillo Subtropical	Yellow		x	
34	Blanco Subtropical	White	x		
42	ETO-Illinois	White	x		
44	AED-Tuxpeño	White		x	
45	Amarillo Bajio	Yellow		x	x
Temperate-Subtropical Materials					
46	Templado Amar. Cris.	Yellow			x
47	Templado Blan. Den	White	x*		
48	Compuesto de Hungria	Yellow		x	x

* Tested in Swat valley

Source: Various reports, CIMMYT International Maize Testing Program, 1974-86 enhanced resistance to leaf blights and stalk rots. Experimental varieties developed from some of these populations have proven outstanding within Pakistan and at many other locations around the world

While the end product of CIMMYT's maize improvement efforts has generally been OPVs, its improved germplasm also has been used extensively in the tropics and subtropics for hybrid development. However, until recently, CIMMYT itself provided little information on the heterotic patterns of its populations, and CIMMYT's own staff generally did not participate "actively" in Pakistan's hybrid development efforts until the mid 1980s.

CIMMYT serves as the hub for a vast international maize germplasm development and testing program in which Pakistani research institutions have been active participants. New and improved genetic resources for Pakistan's subtropical and temperate environments have been developed at an accelerated pace as a result of the efforts of maize scientists in this international network.

CIMMYT's maize improvement program in the 1980s has continued to evolve. New germplasm development work is under way to serve subtropical environments, the intermediate elevations of the tropics, and the highland environments. New germplasm complexes are being developed that possess a range of superior traits, including resistance to various diseases and insects, drought tolerance, cold tolerance, increased nitrogen-use efficiency, and tolerance to aluminum toxicity. Information on the heterotic patterns of CIMMYT's germplasm complexes is being generated and many inbred lines for tropical and subtropical environments have been developed for testing and evaluation by national maize research systems.

Crop Management Research

A second important function of the CIMMYT Maize Program in Pakistan has been promoting crop management research needed to get improved OPVs and production practices into commercial use. Extensive programs of agronomic research have been undertaken since the early 1970s, primarily in collaboration with scientists from NWFP and NARC. Nearly 30 Pakistani researchers have been trained in production agronomy research in Mexico. Even so, crop management research has only effected limited increases in maize productivity at the farm level.

In recent years, CIMMYT and collaborating Pakistani institutions have begun to look at maize as just one element in often complex farming systems, an approach which provides greater insight into the factors that influence the decisions of maize farmers in the country.

The orientation in Pakistan of crop management maize research activities has also broadened with the introduction of an economics component into the PARC/CIMMYT Collaborative Program in 1984. More diagnostic surveys have been undertaken to establish research priorities, and the multipurpose uses of maize are explicitly recognized in the design of experiments. Most of CIMMYT's collaborative work in crop management research has been carried out in irrigated and rainfed areas of NWFP and in the rainfed areas of northern Punjab, southern NWFP, and the Islamabad Capital Territory.

Training Programs

CIMMYT has provided various types of maize training support to Pakistan's research programs during the past 20 years. In-service training began in 1968 when six maize researchers attended courses in the headquarters of the Inter-Asian Corn Program at Suwan Farm (Kasetsart University) in Thailand. Since 1970, when CIMMYT established its in-service maize training program in Mexico, another 49 Pakistani researchers have received training there—29 in a six-month production agronomy course designed to impart operational research skills to relatively junior researchers (Table 20).

Table 20. Pakistani Alumni of CIMMYT In-Service Maize Training by Course Type and Place of Work, 1970-86

Location	Production agronomy	Maize improvement	Experiment sta. mgmt	Total
NWFP	13	5	1	19
Punjab	6	5	1	12
Sind	1	1	-	2
Baluchistan	1	-	-	1
NARC	4	3	1	8
AJK	4	3	-	7
Total	**29**	**17**	**3**	**49**

Source: CIMMYT Training Program Office

A limited number of visiting scientist fellowships have also been awarded to senior Pakistani researchers. These fellowships involve individualized study programs for national maize researchers that generally last from one to three months. The programs include periods of residence in Mexico as well as visits to other national maize research programs in developed and developing countries.

More than 50 Pakistani research workers from provincial and federal research institutions are alumni of CIMMYT's in-service maize training courses in breeding, crop production, laboratory protein quality analysis, and experiment station management. Another 15 Pakistani maize researchers have been to CIMMYT as visiting scientists. As CIMMYT looks ahead, it intends to increase its training opportunities for senior maize researchers.

CIMMYT's headquarters and resident staff have also participated as instructors in Pakistan's in-country maize training courses held under the auspices of the National Coordinated Maize, Sorghum, and Millets Program (NCMP). Courses have been offered in on-farm research techniques, maize pathology research, and more recently in the use of micro-computers in data processing and analysis of research data.

Scientific Information Exchange

CIMMYT has been involved in various activities designed to give Pakistani researchers greater access to useful scientific information about maize. The maize and economics publications produced by CIMMYT are distributed to dozens of individuals and institutions in Pakistan. In recent years, CIMMYT has issued some 10-15 maize-related publications annually—more than double its previous output.

Since 1985, a bibliography service for maize publications has been available to Pakistani research institutions. A bibliographic magazine, the Maize Research Abstract, is co-published with CAB International, UK, six times a year and is distributed to national maize research institutes and university libraries. CIMMYT also assists national maize scientists by making computer searches of the major world scientific databases on specific research topics. The titles and (where available) abstracts of articles identified through these searches have been provided to Pakistani colleagues.

CIMMYT staff posted in Pakistan during the last 20 years have also collaborated with their national program colleagues on dozens of research papers, journal articles, and reports. Since 1985, CIMMYT personnel have been especially active in co-publishing research reports with Pakistani scientists; some 30 publications based on research results from on-farm surveys and experimentation have been prepared and distributed.

Pakistani maize scientists regularly participate in and contribute papers to regional maize research workshops held in Asia every two years through CIMMYT's co-sponsorship. (The next Asian regional workshop will be held in Pakistan in September, 1990.) These regional workshops give national researchers in neighboring countries an opportunity to interact with CIMMYT's maize researchers on a regular basis. Pakistani maize scientists also attend conferences and workshops at CIMMYT headquarters in Mexico.

Resident Maize Advisors

Over the past 20 years, CIMMYT has had five resident advisors in Pakistan for a total of 22 person-years and has provided 6 person-years of short-term consultancies. Considerable amounts of strategic research equipment, vehicles, and operating funds have been provided to facilitate the maize research activities of NCMP, NARC, and the provincial programs.

CIMMYT's first resident maize advisor, Dr. Takumi Izuno, was instrumental in the initial formation of the genetic resources used in the nation's maize improvement programs. Izuno worked closely for seven years with maize researchers in both NWFP and

CIMMYT's first resident maize advisor, Dr. Takumi Izuno, was assigned to Pakistan from 1968 to 1974. There he helped develop the maize breeding programs at MMRI and CCRI. During this period, many new sources of temperate and subtropical germplasm were introduced into Pakistani breeding programs and a number of outstanding open-pollinated varieties were developed and released for commercial cultivation.

Punjab, as well as with maize scientists from West Pakistan's Agricultural Research Service stationed in NWFP and Punjab. He was directly involved in the development of more than a half-dozen new open-pollinated white- and yellow-grain varieties released in Pakistan in the early 1970s.

Dr. A.F.E. Palmer, CIMMYT's first resident agronomy advisor, worked in Pakistan for six years. He helped to initiate off-station maize research in the NWFP and to launch the first coordinated campaigns for transferring improved technology to the farm level. Palmer worked closely with scientists in NWFP, but had little contact with maize researchers in Punjab Province, due to

philosophical differences over the organization of an on-farm research program. Palmer played an advisory role in the establishment and development of NARC and the National Coordinated Maize Program, and was involved in the development of the Pirsabak maize research station (using funds provided largely by the government of Australia). He also helped design the maize research component of an agricultural development project in AJK funded by the World Bank.

CIMMYT's third resident maize advisor, Dr. Richard (Charlie) N. Wedderburn, helped to consolidate Pakistani breeding materials and to introduce more systematic programs for population improvement. Wedderburn was instrumental in incorporating superior tropical germplasm sources into Pakistan's predominantly temperate-based gene pools to increase their resistance to stalk rots and leaf blights. He also provided considerable organizational support for the establishment of the NARC Maize Program and for improving the research station facilities at Pirsabak and Yousafwala. Wedderburn was the first to introduce the use of micro-computers in data processing and the analysis of maize experiments.

CIMMYT's fourth resident maize advisor, Dr. Thomas M. Hart, was assigned in 1984. Hart, however, was forced to leave Pakistan within a year because of illness.

CIMMYT's fifth maize resident advisor, Dr. E. John Stevens, assumed his duties in late 1985. He has paid special attention to germplasm development for the higher elevation maize areas of Pakistan and AJK, focusing on improved cold tolerance. Stevens has suggested new research procedures for handling genotype x environment interactions in maize improvement. Stevens has also been active in promoting the use of improved implements and equipment for land preparation, planting, harvesting and shelling operations. He is responsible for modifications of a small-scale maize sheller that is now being produced commercially (shown on page 84).

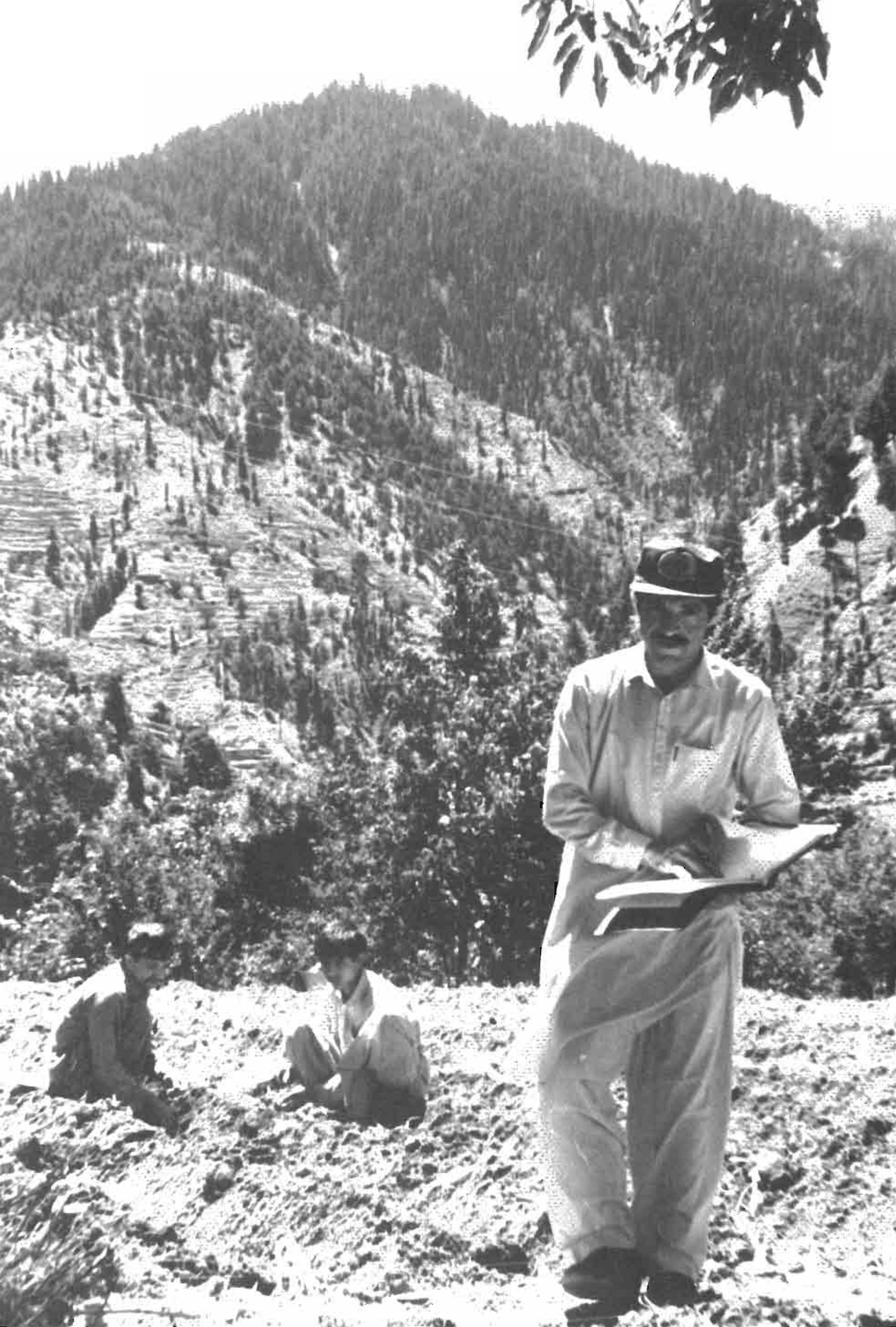
Resident Economics Advisors
CIMMYT's recent work in on-farm research was strengthened considerably through the posting to Pakistan of the Center's Regional Economist for South Asia, Dr. Derek Byerlee, in 1984, followed in 1985 by the addition of Dr. Paul Heisey, a farming

For nearly 20 years, CIMMYT assigned maize staff to work in Pakistan. With the ending of the bilateral collaborative maize program in 1987, CIMMYT serves Pakistan through its South and Southeast Asian Regional Program, headquartered in Bangkok, Thailand. Picture here is Dr. R.N. "Charlie" Wedderburn, Asian regional maize specialist visiting maize experiments at MMRI, Yousafwala. Wedderburn is no stranger to Pakistan, having served as CIMMYT's resident maize advisor during 1979-84.

systems economist, to the PARC/CIMMYT Collaborative Program. CIMMYT's Economics staff have demonstrated through action the very important role that social scientists can and should play within crop management research programs. Their contributions have helped to establish PARC's new Agricultural Economics Research Units (AERUs), located at national and provincial research institutions. Though relatively new and sparsely staffed, the AERUs have carried on a very active program of collaborative on-farm research projects on maize production problems in NWFP and Punjab since 1985. In 1988, Dr. James Longmire took up a post in Islamabad where he is engaged in research on maize seed industry development and other key production issues. This work will provide new information on the current use of varieties and hybrids, on sources of seed, and on utilization, production and maize pricing.

Conclusion of Resident Maize Staff Posting
After nearly 20 years of posting resident maize staff in Pakistan, CIMMYT's direct support and collaboration with the NCMP ended in 1987. With the closing of the bilateral program, CIMMYT's support to Pakistani maize research will be coordinated by three maize staff assigned to the Asian region and headquartered in Bangkok. Although the level of collaboration in maize research between CIMMYT and Pakistani institutions will be less than when the bilateral program was operating, collaboration on international germplasm testing and exchange will continue, and CIMMYT's programs in training, consultation, and scientific information services will also be maintained.

CIMMYT's germplasm development work for areas above 1,800 masl requiring high-yielding flint and dent materials with increased cold tolerance and resistance to temperate-zone diseases will benefit the research programs of CCRI and NARC. There is also collaboration with MMRI to develop new early-maturing populations with yellow grain for the lowland areas of the Punjab. Finally, CIMMYT's expanded work in hybrid development is producing a range of inbred lines for testing and evaluation; these materials will be useful for MMRI, CCRI and NARC.



CHAPTER FIVE

Status of Maize Technology in Principal Agroecological Zones

Maize Agroecological Zones

Maize in Pakistan is produced over a wide range of agroecological zones, for a variety of purposes, and within both market- and subsistence-oriented farming systems. There are seven principal, broad agroecological maize production zones in Pakistan. Each zone differs in water supply, elevation, temperature regimes, and soil types. These can be further disaggregated into smaller domains based on various environmental and cropping system considerations.

The seven agroecological zones represent continuums, and therefore considerable overlap exists from one zone to another (Table 21; Figure 6). Roughly half of Pakistan's maize area is located in warm-season environments and half in cool-season environments. There are another 122,000 ha planted to maize in AJK, with 80,000 ha in mid- and high-elevation zones. Because

Table 21. Major Agroecological Maize Zones of Pakistan, Kharif Season

Zone	Elevation (m)	Water regime	Area ('000 ha)
Warm-Season Environments			
Lowland			
S. Punjab/N.Sind	$\leq$ 600	Irrigated	39
Central Punjab	$\leq$ 600	Irrigated	230
NWFP/N. Punjab	$\leq$ 600	Irrigated	153
NWFP/N. Punjab	$\leq$ 900	Rainfed	92
Sub-Total			**514**
Cool-Season Environments			
Mid-Altitude			
NWFP/Punjab	900-1800	Irrigated	62
NWFP/Punjab	900-1800	Rainfed	121
High-Altitude			
NWFP	1800	Irr/Rainfed	58
Sub-Total			**241**
Winter/Spring			**54**
Total			**809**

Source: PARC/CIMMYT Collaborative Maize Program

of the disputed sovereignty of AJK, this area is not explicitly discussed, although many of the comments made about major agroecological zones found in Pakistan are also applicable to AJK. Furthermore, the maize-producing zones of the Federally Administered Tribal Areas (FATA) have not been classified and are therefore not discussed in this report.

Some of the lowland irrigated environments in Punjab and Sind are ecologically suitable for winter/spring maize cultivation. Should maize production expand during this season, these areas would be categorized as lowland, cool-season environments even though very hot temperatures often prevail in the latter part of the growing cycle.

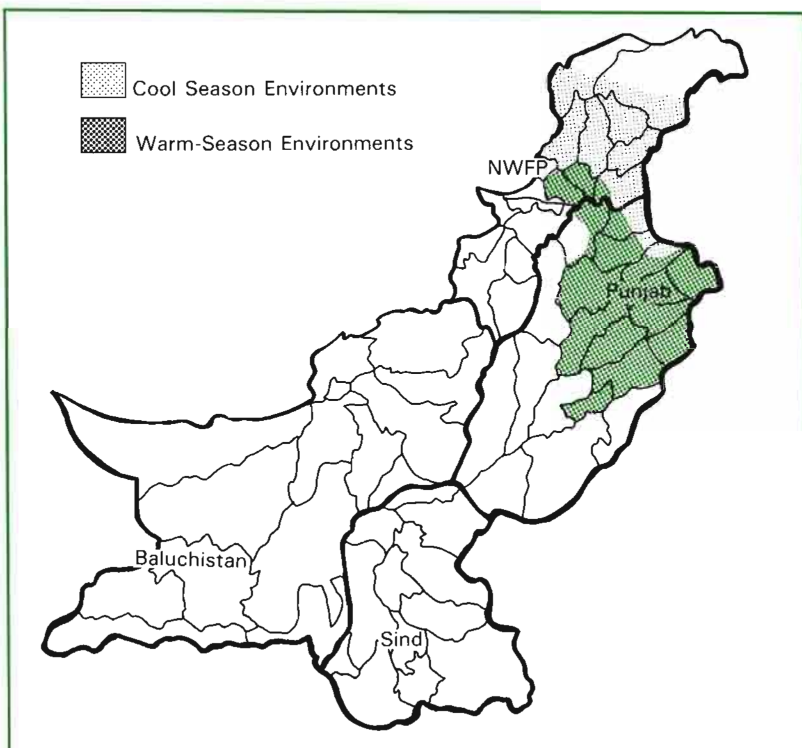


Figure 6. Major Agroecological Maize-Growing Zones in Pakistan.
Source: PARC/CIMMYT Collaborative Maize Program

Low-Elevation Irrigated Zone of Central Punjab

Some 230,000 ha of yellow-grain maize are planted at elevations below 600 masl in the irrigated plains of central Punjab during the kharif season, from July-August to October-November (Table 22). In addition, some 30,000 to 40,000 ha are planted during the winter season (Feb-March to June-July); but maize production from this season is not recorded separately in official statistics. Official grain yields in this zone are in the 1.2 to 1.5 t/ha range, although actual yields (where maize is harvested for grain) are probably more on the order of 1.5 to 2.0 t/ha.

Table 22. Maize Area of Districts in the Low-Elevation Irrigated Zone of Central Punjab Province

Districts	Area (ha)
Faisalabad	46,200
Sahiwal	31,900
Jhang	27,800
Toba Tek Singh	25,800
Multan	24,100
Sargodha	23,800
Sheikhupura	13,900
Vehari	12,300
Okara	9,400
Kasur	6,300
Lahore	5,100
Other	3,100
Total	**229,700**

Source: PARC/CIMMYT Collaborative Maize Program

Summer Season Maize—Maize in central Punjab is grown primarily during the summer season within a mixed cropping zone situated between the predominantly rice/wheat zone to the north and the predominantly cotton/wheat zone to the south. Generally, maize is grown in small, scattered plots; extensive monoculture is not common. Weather during the summer season is hot and relatively humid (MMRI, 1983).

The main soil type in this mixed zone is silty loam, which is less suitable for paddy rice, and its relatively high humidity makes the area less suitable for cotton as well; nevertheless, both of these crops are grown, and the area planted to rice has been increasing.

Heat stress during the summer season causes plant mortality at the early vegetative stages and affects flowering and grain-filling during the later stages. Soil salinity due to high water tables and waterlogging are also common. Drought stress is frequent due to irrigation water shortages. Leaf blights caused by *Helminthosporium* spp. and stalk rots by *Fusarium* spp. are the major disease problems, and stem borer (*Chilo partellus*) and shoot fly are the major pests.

Approximately 60-70% of the maize in this zone is grown for grain/green fodder by small farmers and 30-40% of the maize area is sown to maize for use as a specialty fodder crop by farmers with relatively large holdings (Khan Bahadur, pers. communication). While grain is retained for home and farm uses, surplus production is sold to private agents (beoparis) at the farm gate. Where progressive thinning is practiced to provide green fodder, stands at harvest are normally 15,000 to 20,000 plants below optimum density. In specialty fodder maize fields, high plant densities are used (80 kg/ha) to maximize total dry matter production, and the crop is harvested at the mid-reproductive stage (Akhtar et al., 1986).

Tractors are increasingly employed for land preparation (using a tined cultivator followed by a planking during the last plowing), although bullock power is still very important. Small-scale farmers use bullocks or hire tractor services. Farmers have different methods for planting maize, but line planting and broadcasting the seed are usually involved (Wedderburn et al., 1984). Local producers employ one of four different practices: 1) the 'kera' method of dropping seed by hand in a furrow created by bullock-drawn plow (used on 50% of the area), 2) broadcasting the seed and then covering it up using cultivators drawn by tractors or bullocks (38% of area), 3) the use of a cotton seed drill (mainly large-scale farmers; 8% of the area), and 4) the 'pora' method in which a tube is attached to a traditional plough and the seed dropped into a funnel at the top of the tube (6% of the area). Maize planters are not widely used in the zone. Broadcasting seed is the cheapest and quickest planting method. However, it often results in poor stand establishment and uneven germination/plant emergence. The pora method is the most time-consuming and costly. Higher seed rates are used with the broadcast method (40 kg/ha) than with the kera, seed drill, and pora methods (30 kg/ha).

Planting is generally done during July and August. It can be delayed by early monsoon rains, by competition with other crops, or as a means to combat damage from the corn stem borer and wild pigs. Poor stand establishment is a major yield constraint, with plant populations often 20-40% below optimum, even for grain production.

The currently recommended improved varieties are Sultan for early planting and Sunheri for late planting (August). However, farmers generally plant mixtures of local varieties, older improved varieties such as Neelum, Akbar, and J-1, and some of the newer varieties like Sultan and Sunheri. Approximately 85% of the seed used is farmer maintained (Tetlay, 1987). Some of the large-scale farmers who are Rafhan contract growers also use the company's hybrids, although these are less suitable for summer season production because of their susceptibility to leaf blights. Some farmers also purchase seed of improved genotypes from MMRI, Yousafwala.

Almost all farmers use chemical fertilizers. A common practice is to apply all of the phosphorus and some of the nitrogen at planting and then to side dress additional nitrogen at the first irrigation. The average dosages on maize in this zone are 73 kg/ha N and 27 kg/ha P (Wedderburn et al., 1984).

Weeds can be a serious problem in this zone. Farmers who line plant control weeds by performing one or two inter-cultivations using a desi plow drawn by bullocks. In broadcast-planted fields, weed control is accomplished by hoeing or hand-cutting weeds for fodder. Large-scale farmers sometimes use pre-emergence herbicides, such as Primextra. Plant protection against stem borer is very important. Relatively few farmers, other than Rafhan growers, however, use insecticides on maize.

The major opportunities for increased productivity in maize are 1) use of improved varieties with stalk rot and leaf blight resistance and heat tolerance, 2) improved stand establishment, which would be aided by the introduction of a suitable maize planter or drill, 3) improved weed control, 4) more balanced and optimum fertilizer use, and 5) ridge and furrow culture to reduce problems associated with irrigation and monsoon flooding.

Winter/Spring Season Maize—Approximately 15,000 to 20,000 ha of maize is planted during the spring season in this zone. This crop has been introduced by Rafhan Maize Products Ltd as a means of increasing the number of months per year for maize grain offtake to supply its wet-milling factory in Faisalabad. Rafhan contracts from 10,000 to 20,000 ha of maize production (depending on its needs at the factory) among a list of 300 to 400 farmers in Faisalabad, Toba Tek Singh, Jhang, Sahiwal, Okara and Multan districts. Rafhan growers are generally large-scale farmers (10 to 50 ha) who have planted potatoes in the preceding season. Rafhan growers are provided with hybrid seed developed and produced by Rafhan, as well as fertilizers, pesticides, and technical support from its agronomists stationed in Faisalabad, Sahiwal and Multan. Inputs are provided on credit, their value being deducted at the time of harvest.

With currently available hybrids, cold winter temperatures delay planting until late February or early March (even though potatoes are harvested in Dec-Jan). This late planting date means that the crop enters the flowering stages in May-June—the time of the hottest temperatures in central Punjab (average daily temperature is 39°C)—inhibiting pollination. A technique has been developed in which the fields are flooded to create a micro climate that permits pollen shedding. Hot temperatures at night considerably increase transpiration and respiration rates and reduce dry matter accumulation. Heat stress during grain filling also reduces yields. Even with these stress problems, the average yield of Rafhan growers is about 3 t/ha—twice that of the national average—and the top 20% of contract fields yield above 5 t/ha.

Major ways to increase productivity are 1) the development of intermediate-to-early high-yielding varieties and hybrids with cold tolerance in order to plant earlier and thus allow flowering during April and more flexible crop rotations, and 2) improved stand establishment to achieve optimum densities for grain production.

Low-Elevation Irrigated Zone of NWFP and Northern Punjab

This irrigated maize zone below 900 masl covers 153,000 ha mainly in the Mardan and Peshawar districts of NWFP, the irrigated portions of the Bannu and Kohat districts, and in the small irrigated areas of a half-dozen other districts of NWFP and Punjab (Table 23). Official average yields for this zone range from 1.5 to 2.0 t/ha. However, data from over 500 crop cuts of commercial fields in 1983-86 indicate that actual yields range from 2.0 to 3.5 t/ha (Wedderburn et al., 1984; Khan and Haq 1985; Hussain et al., 1986).

Table 23. Maize Area of Districts in the Low-Elevation Irrigated Zones of NWFP and Northern Punjab Province

District	Area (ha)
Mardan	51,300
Peshawar	44,500
Malakand	5,200
Abbottabad	3,100
Mansehra	3,100
Attock	8,800
Kohat	4,200
Rawalpindi	3,800
Bannu	13,600
D.I. Khan	2,200
Gujrat	8,000
Gujranwala	5,200
Sialkot	3,200
Total	**153,100**

Source: PARC/CIMMYT Collaborative Maize Program

The cropping patterns in this area are complex. Maize is the major cereal crop during the summer season, although it is often considered by the farmer to be a ''fill-in'' between various cash crops. In the Mardan and Peshawar districts, maize is grown primarily after wheat (65%), with secondary rotations after tobacco (20%) and other crops such as sugarbeets (14%) (Hussain et al., 1986).

Nearly all farmers use tractors for land preparation. Maize is usually planted late 1) because of conflicts with higher value crops within the cropping system, 2) to avoid the stem borer attacks associated with earlier planting, and 3) because of shortages of irrigation water (Hussain et al., 1986). Heavy rains and winds in September can cause flooding and extensive lodging.

Farmers have historically tended to line-plant using bullock power and the kera method with seeding rates of 40 kg/ha, only a little higher than the rate recommended by the research and extension services (30 kg/ha). But with a decline in the availability of bullock power and the lack of suitable implements for mechanized line-planting using a tractor, broadcast seeding is on the increase (now 40% of the area).

Most farmers use one of two local varieties: Local white (77%) or Swabi white (11%); only 5% use the recommended improved varieties (Hussain et al., 1986). The currently recommended varieties are Sarhad white and Sarhad yellow for early planting and Azam for late planting.

Almost all farmers (94%) use nitrogenous fertilizer, but only 33% use phosphatic fertilizer. The average fertilizer application is 77 kg/ha N and 17 kg/ha P. Weed control is performed primarily by hoeing and inter-cultures in line-planted fields.

Increased productivity could be obtained by 1) the use of improved varieties, 2) mechanized line-planting using a low-cost maize planter, 3) more balanced fertilizer use, and 4) ridge and furrow culture to reduce lodging and damage cause by irrigation and monsoon flooding.

Low-Elevation Rainfed Zone of NWFP and Northern Punjab
This low-elevation (below 900 masl), rainfed, white- and yellow-grain maize zone accounts for approximately 91,600 ha (Table 24). It includes districts on the Pothwar plains and in the lower piedmont areas of the mountains to the north and east. Official average yields are between 0.6 and 1 t/ha, making it the lowest-yielding maize zone in the country.

Table 24. Maize Area of Districts in the Low-Elevation Rainfed Zones of NWFP and Northern Punjab Province

District	Area (ha)
Abbottabad	32,000
Rawalpindi	21,000
Attock	2,700
Islamabad	5,800
Sialkot	7,100
Swat	10,000
Mardan/Peshawar	3,600
Bannu	1,700
Kohat	7,700
Total	**92,600**

Source: PARC/CIMMYT Collaborative Maize Program

The most widespread rotation is wheat/maize. Maize is mostly grown on lepara land, which is fertilized regularly with farmyard manure. Farmers attempt to plant as soon as the monsoon rains come in June and July. Shortages of labor and tractors for land preparation and the rapid onset of monsoon rains mean that there are very few days available in the planting ''window'' (PARC, 1987).

Maize seed is generally broadcast at high rates (60-100 kg/ha). Nitrogenous fertilizer is used, but little phosphorus fertilizer is applied directly to maize (up to 50 kg/ha of phosphorus may be applied on the preceding wheat crop). Average dosages range from 50 to 60 kg/ha N and 0 to 12 kg/ha P (PARC, 1988). Monsoon rains often delay inter-culture and weeds are a serious problem. Conversely, drought is often prevalent during the grain-filling stage in September.

Local varieties are generally used, although the activities of PARC's BARD project have helped to introduce the improved variety Azam. This variety has been enthusiastically received where seed has been made available (PARC, 1987). CCRI, MMRI and NARC recommended the following improved varieties: Sarhad white and Sultan (Y) for early planting, and Azam, Gauher, and Sunheri for late planting. Only a few yellow maize varieties are grown in the zone since—with the exception of Azam and Gauher and some local early yellow maize varieties—they are too late-maturing to meet farmers' requirements.

Maize is typically thinned for green fodder up to maturity and high population densities are employed. Because of the high plant densities and frequent drought stress, very high proportions of barren plants occur. In the Islamabad Capital District, barren plants can account for 55% of the total plant population in high-density fields (Sheikh and Malik, 1987).

Major opportunities for increased productivity include 1) improved varieties with earlier maturity and/or drought tolerance, 2) more effective methods of weed control (probably chemical), 3) better management of plant stands, 4) more balanced and optimum use of N and P fertilizers, and 5) introduction of acceptable alternative fodder sources.

Mid-Elevation Rainfed Zone of NWFP and Northern Punjab

This rainfed white-grain maize zone of 120,500 ha is located primarily in the Mansehra and Swat districts, between 900 and 1800 masl, and in small parts of Abbottabad and Rawalpindi in the Murree hills (Table 25). Official statistics for average yield in this zone range from 1.0 to 1.5 t/ha. Crop cut surveys put the actual yields at 2.5 to 3.7 t/ha, depending on moisture availability (Byerlee and Hussain, 1986).

Table 25. Maize Area of Districts in the Mid-Elevation Rainfed Zone of NWFP and Northern Punjab Province

District	Area (ha)
Mansehra	45,000
Swat	43,000
Abbottabad	23,000
Rawalpindi	9,500
Total	**120,500**

Source: PARC/CIMMYT Collaborative Maize Program

Almost all maize is planted after wheat there, usually under marginal moisture conditions in late May or early June following the onset of early monsoon showers. Most farmers use local varieties. In Mansehra, the local variety, Hazara Double, is used for normal planting and the short-season variety Sathi for late planting. Recommended varieties for this zone are Sarhad White for the lower reaches and early planting and Azam and New Shaheen for the higher reaches and in late-planting situations. Farmers in the higher reaches of this zone would like varieties with even shorter growth cycles for more successful double cropping of wheat/maize.

High seed rates (80-100 kg/ha) and multiple planting dates are the typical practices: stands are thinned continuously up to maturity for green fodder, although less than in some other areas. Planting before the monsoon sets in often results in low germination when rains come late and are less intense than normal; hence, plant stand establishment is highly variable. Late planted fields face serious weed competition.

Most farmers apply nitrogen fertilizer (average dose 70 kg/ha) but only 22% apply phosphorus (average dose 12-15 kg/ha). The response to phosphorus is variable, being lower in Swat and higher in other areas.

Disease problems include leaf blights and stalk rots, and rust and head smut in the higher elevations. Common pests are the stem borer, cut worm, and shoot fly.

Major strategies for increased productivity include 1) the use of improved varieties, especially early maturing ones that will allow planting after monsoons start, 2) better weed control for late planting (probably chemical), 3) more uniform stand establishment, and 4) the introduction of acceptable alternative fodder crops.

Mid-Elevation Irrigated Zone of NWFP and Northern Punjab
This mid-elevation irrigated white-grain maize zone includes 62,100 ha between 900 and 1800 masl and covers the irrigated valleys of Upper Swat and Kohistan districts, along with smaller areas in Dir, Chitral, Mansehra and Abbottabad. Official yield reports for this zone range from 1.2 to 1.6 t/ha. Crop cut surveys, however, indicate that yields actually average 3.0 to 4.0 t/ha, the highest in Pakistan.

Table 26. Maize Area of Districts in the Mid-Elevation Irrigated Zone of NWFP

District	Area (ha)
Swat	20,000
Kohistan	23,000
Dir	9,400
Chitral	3,500
Mansehra	3,000
Abbottabad	3,200
Total	**62,100**

Source PARC/CIMMYT Collaborative Maize Program

Maize is the dominant crop during the summer season, accounting for 75% of the cropped area, followed by rice (19%) and vegetables (6%) (Byerlee et al., 1987). Maize is grown as a dual-purpose grain and green fodder crop; high yields are common for both products (4 t/ha grain; 4-5 t/ha green and dry fodder). Increasingly, however, maize is becoming a low priority crop within the farming system, as farmers switch to higher value cash crops, such as tree fruits and garden vegetables.

Most farmers use local varieties or older improved varieties, such as Zia and Changez. Recommended varieties are Sarhad white for early planting in the lower reaches and Azam and New Shaheen for late planting in the higher reaches. Maize varieties with the maturity of New Shaheen are desired by many farmers who follow a vegetable/maize rotation.

Seed is broadcast at high rates (80-100 kg/ha). The "seel"—the process of taking an animal-drawn plow through a broadcast seeded field at a row spacing of 25-30 cm after crop emergence—is used to control weeds and thin plant stands. From the time of the seel onward, continuous thinning of green plants for fodder occurs.

Virtually all farmers use nitrogen fertilizers and some 50% use phosphorus fertilizers. The average rate of nitrogen application has increased from 60 to 100 kg/ha, while phosphorus applications have remained around 30 kg/ha (Byerlee et al., 1988).

Important diseases are the leaf blights and stalk rots, in addition to rust and head smut in the higher elevations. Problem pests include the stem borer, cut worm, and shoot fly.

Local productivity could be enhanced through 1) the use of improved varieties, including earlier-maturing varieties to allow intensification of cropping and 2) the development of varieties that have high grain and green fodder production potential under high densities.

High-Elevation Zone of NWFP

At least 57,200 ha of white-grain maize (and probably much more) is grown above 1,800 masl in Upper Swat, Kohistan, and Dir districts under both irrigated and rainfed conditions (Table 27). Actual maize yields in this zone are quite high (3-4 t/ha) and fodder productivity is good, due primarily to the longer growing season and intensive cultural practices.

Maize and potatoes are the primary summer season crops and are often grown in a two year rotational cycle. The farming systems tend to be relatively "closed" in the sense that farmers purchase few inputs and produce little market surplus. The major exception is the potato growers that use NPK fertilizer and imported seed. However, farmyard manure is applied and the small plots are intensively managed

In these areas, maize is generally grown as a monocrop and only one season per year is possible Local varieties are most common, although the improved early maturing variety, New Shaheen, has

Table 27. Maize Area of Districts in the High-Elevation Mixed Irrigated/Rainfed Zone of NWFP

District	Area (ha)
Swat	19,200
Mansehra	21,600
Abbottabad	4,000
Kohistan	3,600
Chitral	3,500
Dir	5,300
Total	**57,200**

Source PARC/CIMMYT Collaborative Maize Program been introduced in Upper Swat and is produced and distributed through farmer seed producer groups. At this elevation, however, Shaheen is a full-season variety. In the lower elevations, farmers can also grow a spring crop of wheat or oats, primarily as a fodder source. Insect damage, especially from cutworms and stem borers, can be a problem.

Productivity in the zone could be improved by 1) the development of very early-maturing varieties with cold tolerance and good resistance to rust, smut and leaf blights, and 2) the introduction of earlier maturing varieties of wheat and other crops, including food legumes.

Adoption of Improved Maize Technologies

Two major technological changes have occurred in maize production in Pakistan over the past 20 years. First, the increased use of fertilizers (especially nitrogen-based ones); and second, the rise of tractors as a dominant power source for land preparation.

Sporadic adoption of the improved varieties developed by research services has also occurred, but largely through localized seed sales in areas near the maize research stations and through the various informal seed production campaigns conducted by research and extension organizations. In 1984-85 and 1985-86, the certified seed produced in Punjab and NWFP was only enough to plant about 30,000 to 35,000 hectares of maize land, or 4% of the national area.

While a few farmers adopt other improved practices (for example, Rafhan contract maize growers in central Punjab use line sowing, insecticides, and hybrids), there is a wide gap between farmer practices and those recommended by the research and extension services (Table 28). Widespread and deliberate non-adoption of many components of the package of recommended practices calls into question the suitability of either the recommended technology or the systems for transferring technology to the farmer.

Some of the maize production recommendations of the research and extension services may be less appropriate for farmers who rely on maize for grain and fodder uses (see the following section). The main constraint restricting increased productivity, however, appears to be the limited distribution of certified seed of high-yielding varieties and hybrids.

Table 28. Comparison of Maize Production Practices in Selected Districts of Pakistan

% who use	Hazara	Mardan	Swat	Toba Tek Singh/ Faisalabad
Improved Seed*	4	5	8	14
Tractor Plowing	93	68	66	28
Broadcasting	96	42	100	19
Fertilizer	87	90	90	99

* Refers to recent new varieties and seed that is reasonable true to type

Sources: (1) Byerlee and Hussain 1986; (2) Hussain *et al.*, 1986; (3) Byerlee *et al.*, 1987; (4) Tetlay *et al.*, 1987

Issues in Development of Maize Technologies

Maize research institutions still need to do more to understand farmers' circumstances, if they are to develop improved technologies which achieve greater success in diffusion. Several of these issues are addressed below.

Maize as a Multipurpose Crop—Unlike the case of other cereals, the optimum maize plant population for grain production is significantly lower than that for maximum dry matter production. At population densities higher than the optimum for grain production, barrenness causes reduced grain yields. Thus, crop management for combined grain and fodder production requires trade-offs in grain and fodder yields.

One of the most complex and controversial issues in maize productivity is how to meet both the grain and fodder needs of the farmer who relies on maize as a multipurpose crop. Fodder from the maize field is obtained in three forms: by cutting green stalks, by cutting weeds, and by saving the dry stover. The relative value of each varies in different farming systems, and the supply of fodder will depend on how the farmer's management practices (seed rate intensity, the seel, and plant removal) interact with climate. Fodder utilization is also influenced by the fodder quality-quantity characteristics peculiar to maize (such as stalk thickness), the overall fodder blends used by the farmer, and the form in which the fodder is ingested (chopped or unchopped). Preliminary research, for example, indicates that chopped maize stalks (using a fodder chopper) are digested more completely by livestock than whole stalks.

The importance of maize as a fodder varies according to the type of farmer and the region. In the northern maize-growing areas it is extremely important to the farmer. A common recommendation by research and extension services has been to plant separate grain and fodder plots so as to maximize grain yields. Although farmers frequently grow separate fodder crops, such as shaftal (clover) or berseem (Egyptian clover), they continue to use maize as a multipurpose crop, despite extensive on-farm demonstrations to induce farmers to consider maize primarily as a grain crop.

The explanation for this can be found in the characteristics of local production systems. In areas where there is a high number of animals per farm unit, income from maize grain is secondary to income from the animals, which also supply important amounts of manure for maintaining soil fertility. The value of the maize plant as a fodder source, therefore, is often equal to that of the plant as a grain source. In addition, tenant farmers commonly receive all of the green fodder (and sometimes all of the dry fodder), but only half of the grain, providing an added incentive for management practices that favor fodder production.

Sowing maize at high plant densities to increase fodder undoubtedly reduces maize grain yields. It has also been estimated that 1.2 t/ha of grain yield is lost when maize is thinned at the 12-leaf stage (Chaudhry, 1983). This loss, however, may be compensated for by the value of the fodder produced (Byerlee and Hussain, 1986). Other calculations indicate that grain yield in a field grown only for grain would have to be double the grain yield obtained in a field grown for both purposes, in order to be profitable for the farmer. Furthermore, because of the progressive way that the maize field is thinned, the loss in grain yields may not be as serious as previously hypothesized (Fischer and Javed, 1986). Thus, the farmer may indeed be quite justified in producing both grain and fodder in the same field, given his available alternatives.

The issue of trade-offs in grain and fodder production need further research. The potential of other fodder sources (including such specialized systems as a maize/cowpea mixture), more effective use of crop residues, and improvements in natural pastures need to be studied. But maize researchers ought not reject out of hand farmers' practices. Indeed, the best way to improve the current system may be for maize breeders to develop improved varieties for dual grain-fodder uses. This would require selection under high plant density against barrenness and for leafy, "stay green" genotypes.

Germplasm Development—While improved varieties have not been developed for all agroecological zones, excellent yellow and white grain open-pollinated varieties of full-season and intermediate-to-early maturity exist for environments below 1,600 masl with normally adequate moisture. Moreover, the three maize breeding programs at CCRI, MMRI and NARC have several populations from which to extract superior open-pollinated varieties and inbreds for hybrids.

During the 1980s, increasing amounts of tropical germplasm have been incorporated into these populations, previously comprising mostly (or exclusively) temperate-zone germplasm. This mixing of tropical and temperate germplasm has not only led to greater yield potential but, more importantly, has incorporated new sources of resistance to stalk rots, leaf blights, rusts, and smuts.

In recent years, these breeding programs have directed more attention to previously neglected agroecological niches such as higher elevations and spring maize environments. Current breeding priorities are focused on improving the tolerance or resistance of those populations to various stresses and on using them more effectively for producing inbred lines as well as synthetic varieties. In particular, the heterotic patterns of national breeding materials are now being evaluated more systematically.

NARC and CCRI have placed greater emphasis in recent years on the development of earlier-maturing germplasm with good disease resistance for rainfed (barani) and higher elevation areas. These materials are showing improved uniformity and enhanced resistance to stalk rots and foliar diseases, two characters that had been especially hard to incorporate into in early-maturing populations in the past.

How environment x genotype interaction should be handled in the breeding programs, especially for the higher elevations and for combined grain/fodder production, is a matter to be resolved within the maize improvement research system. A series of pilot breeding projects have been initiated since 1985 using nontraditional screening sites to obtain more information on appropriate locations for research on specific traits such as cold tolerance and early maturity. In addition, the management of populations for both inbred line and synthetic variety development is still being worked out.

The priorities of Pakistan's maize breeding programs require some reorientation. First, germplasm improvement programs overemphasize maize for grain production, despite the multipurpose potential of the crop. In central Punjab, some 30-40% of all maize is produced as a specialty fodder crop; another 10-15% is grown as a grain/green fodder crop with continuous thinning. In NWFP, most farmers depend on maize as a grain/green fodder crop. These utilization patterns underscore the importance of developing improved maize varieties for grain, for dry fodder, and for mixed grain/green fodder uses. In Punjab, research is underway to produce both grain and fodder genotypes at two separate institutions—MMRI in Yousafwala and the Fodder and Forage Institute at Sargodha—but little collaboration presently takes place between these institutes.

Increased attention should also be given to developing varieties with greater tolerance to environmental stresses and with a range of maturities to fit various agroecological zones and farming systems. In particular, there is a need for very early-maturing varieties for the higher elevation areas, where 250,000 ha of the nation's maize lands are located. To address the germplasm development requirements of these zones, breeders need to conduct their crossing and screening programs at representative locations within the zones and not at the main breeding stations.

Planting Method—Most maize is planted in Pakistan by broadcasting the seed, which is then incorporated using a plank drawn over the field by either a tractor or bullocks. In general, farmers have consistently rejected the recommendation of researchers and extension agents to line plant maize, giving the following reasons:

1) It requires considerably more labor and time, in general.

2) The kera method requires the use of bullocks, and many farm families have sold their bullocks since tractors have come into use.

3) No tractor-drawn maize planter or rabi drill is available in the area to do line planting. (This method would require the same man-days per ha as broadcasting and seed incorporation by tractor; the availability of suitable equipment would make line planting attractive in some areas currently using broadcast sowing.)

Farmers also perceive a number of benefits to broadcasting seed other than simply saving time and money. One real advantage is that broadcasting seed results in more fodder. Farmers also believe that broadcasting gives a more even seed distribution. Since the seed is mixed into the soil, it ends up resting at slightly different depths, some closer to the surface to take advantage of early monsoon showers and some slightly deeper to reach residual moisture. This provides additional security for germination and seedling emergence, but precludes mechanical harvesting.

Weed Control—The nature of weed problems in the maize-growing zones differs substantially. In general, weed populations are higher in rainfed areas. In Rawalpindi, Islamabad and Abbotabad, weeds substantially reduce yields. In irrigated areas, smaller farm size, more intensive cropping patterns, crop rotations, and delaying of planting until after weeds have germinated (by pre-planting irrigation or early rains) all have helped to reduce the weed problem.

In the lower- and mid-elevation zones, the seel (inter-culture with a desi plow) is often the major weed control method. In the rainfed areas, tractors are increasingly used for the seel by removing the front tines of a cultivator. In general, farmers attempt to control early weed growth through this technique, leaving some weeds which are removed as fodder later in the cycle. In theory this system can be quite effective: it is inexpensive and, when performed on time, *does* control weeds (in addition to plant population density). Remaining weeds do little damage, since the maize crop is well established and the remaining weeds have value as fodder. In practice, however, the seel is becoming less effective. In late-planted fields, the seel must be performed during the peak of the monsoon rains when it is difficult to get into the field, especially in areas with medium-to-heavy soils. Moreover, farmers who increasingly depend upon borrowed bullocks or a tractor are uncertain of obtaining these services at the right time.

Manual weed control methods are also used. Hoeing is common in the irrigated area of Peshawar and Mardan and some areas of Swat, but this method is expensive, requiring about 20 man-days of labor/ha (Byerlee and Hussain, 1986). Its high cost opens up opportunities for introducing other means of weed control.

Pre- and post-emergence herbicides such as Primextra and Banvel offer great potential for improved weed control, especially in the following situations:

1) Fields in rainfed areas where mechanical weed control is impossible or ineffective due to heavy rains
2) Fields in irrigated areas which are hoed, especially by hired labor, and where the cost of labor is higher than that of herbicides
3) Systems growing fodder sources other than the weeds that would be destroyed by herbicides

Herbicides appear to offer high returns on investment, especially in rainfed areas characterized by shortages of labor and of equipment for mechanical weed control. Post-emergence herbicides are especially suitable, since the farmer can wait for the rains and apply the herbicides only if plant stand establishment and weed competition warrant the use of this relatively expensive input. However, the loss or chemical contamination of weeds in systems where they are a source of fodder will have to be addressed by the research system if herbicide use is to gain widespread acceptance in farm areas near cities (where livestock are especially important). Finally, education on the safe use of herbicides must be provided, and the availability of this input assured.

Fertilizer Use—Fertilizer is used on maize in both irrigated and rainfed areas. In particular, its use in rainfed areas has increased substantially during the last decade. Few farmers in NWFP, except in Swat, are using phosphatic fertilizers. In some cases, farmers do apply phosphorus to the wheat crop preceding maize (as in Islamabad Capital Territory). However, significant numbers of farmers do not use phosphorus on either wheat or maize (as in Mardan District). In such cases, significant nutrient deficiencies may exist. In rainfed areas, there is likely to be a significant difference between the lepara land close to the village and the mera land further away from the farm household, since farmyard manure is extensively applied in the first case and not at all in the second. Hence, fertilizer recommendations need to be developed for specific cropping patterns and land types. The present tendency toward a blanket recommendation on fertilizer dosages fails to take into consideration the very different traditional methods of soil fertility management practiced by the farmer.

Mechanization—While mechanization has been widely adopted in Pakistan for certain production operations, the use of tractors in deep plowing, planting, inter-culture and harvesting has not been optimized. A recurring problem has been a lack of the implements needed for efficient tractor use. In many cases, the only implements a farmer has are a tined cultivator and a plank.

Separate agronomic trials conducted by the PARC/CIMMYT Collaborative Program, the BARD Project, and the Italian Crop Maximization Program have clearly shown the impacts on yield levels and productivity that can be achieved through the use of various tractor-powered implements. Considerable opportunities exist to increase maize productivity in Pakistan through the use of improved farm machinery such as:

- The moldboard plow for deep primary tillage in soils where the development of a shallow plowpan layer and soil compaction reduce root development (Malik, 1986)

Although maize land is frequently prepared by tractor, most other maize production operations are done by hand. Considerable gains in maize productivity can be realized by bringing other tractor implements into use for minimum-tillage land preparation, row planting, fertilizer applications, weed control, and harvesting/shelling operations. Pictured here is a modified maize planter being tested at NARC's Farm Machinery Institute, which is charged with developing new types of farm implements for use in Pakistani agriculture.

• Minimum and zero-till planters to reduce conventional tillage costs, resulting in a quick turnaround between cropping cycles and an expanded planting "window"
• Conventional maize planters and drills to improve stand establishment, achieve more uniform application and appropriate placement of fertilizers and pesticides, and lower the cost of harvesting and grain shelling operations

While excellent farm machinery exists for all of these operations, most of this equipment must be imported, which often means that the cost is too high for adoption by farmers and custom tractor

operators. However, in most cases, there is considerable scope for manufacturing a much greater array of farm machinery in local foundries and machine shops. Greater availability of such tractor-powered equipment offers one of the best strategies for increasing the productivity of maize and many other crops.

Priority Geographic Zones for Research Attention

All of the nation's maize-producing zones would benefit from the availability of improved seed and a more responsive, farmer-focused research system to address crop management problems. However, three zones have been identified below for priority research attention. Success in raising maize productivity in these zones would produce economic as well as equity benefits.

Mid- and High-Elevation Zones—Some 250,000 ha— 25% of the nation's total maize area—are found in areas above 900 masl, largely located in NWFP. (AJK also has about 60,000 ha in mid-to-high elevation areas.) Little maize breeding research has been conducted explicitly for these higher-elevation zones, which are home to some of Pakistan's poorest people.

Farmers in high-elevation areas need high-yielding, earlier maturing varieties with enhanced cold tolerance. The early maturing varieties presently available in Pakistan (classified as early maturing at Pirsabak, NWFP) become intermediate-to-late season varieties as they move up the altitude gradient. Breeding maize varieties explicitly for these higher elevation zones would have a major impact.

Most maize improvement work in NWFP is carried out at Pirsabak, at 500 masl. (The highest altitude station used for maize breeding in Pakistan is the NARC station at Islamabad, at 640 masl.) While there are research sub-stations in NWFP at the higher elevations which can be used for such purposes, current CCRI budget limitations restrict breeding programs at these sites.

The green fodder requirements of farmers in the higher elevation areas—presently supplied by maize—must also be addressed by Pakistani researchers (Stevens et al., 1986). Preliminary research suggests that where adequate moisture is available and farmers progressively thin their fields down to 70,000-80,000 plants per ha by harvest, losses in grain yield can be more than

Some 250,000 ha of maize in Pakistan are found in highland areas, ranging from 900 to 2,500 meters above sea level. Maize in these highland areas is invariably grown as a multi-purpose food, fodder, and forage crop, and used almost entirely on the farm. Maize's multi-purpose uses have only recently been recognized in the research agenda of most institutions, which traditionally were only concerned with maize as a grain-producing crop, disregarding its importance as a green fodder source in the farming system.

compensated for by the value of the green fodder that is produced. Breeding priorities for the mid-to-high elevations, therefore, should include the development of varieties which optimize both grain and total dry matter production Selection against barrenness (or for prolificacy) and for leafy genotypes with stay-green characteristics should be important breeding objectives

Lowland Rainfed Zones—One of the most promising opportunities for increasing national production in the short-term is to raise yield levels in the rainfed areas of northern Punjab and NWFP Such areas include low and mid-elevation agroecological zones and account for nearly 100,000 ha of low-yielding maize (1.0 t/ha or less)

There is a general need for germplasm with early maturity and drought tolerance in such areas. Crop management research should address such issues as 1) stand establishment and management, 2) weed control, and 3) more balanced fertilizer use. The prevailing practice of planting at high densities causes considerable barrenness among harvested plants in the rainfed areas of northern Punjab and southwestern NWFP. The practice of broadcasting seed is also problematic from two standpoints. Under drought-stress conditions, high plant densities seriously affect grain production potential as well as total dry matter accumulation. Moreover, many farmers in rainfed areas of Rawalpindi and Islamabad have off-farm employment. They are thus unable to thin plant stands or control weed populations and suffer substantial yield losses as a result.

The development and introduction of a low-cost maize planter could overcome the cost and time drawbacks associated with currently available methods of line planting (principally the 'kera' method). Thus, the farmer could work with an optimal planting density from the very beginning, and inter-culture could be used widely as an effective means of weed control. Chemical methods also hold promise, but particular attention should be paid to risk averting technologies such as post-emergence herbicides (rather than the pre-emergence herbicide currently recommended), so that farmers do not have to purchase the chemicals until they are certain of an adequate stand establishment and rainfall for plant growth and development. Finally, alternative fodder sources, especially for maize areas near urban centers, will have to be developed to compensate for the loss of weeds and thinning as a green fodder source.

NARC's strategic location near the rainfed zones in which maize is grown gives it an advantage in assuming leadership for both maize breeding and crop management research there. It makes little sense for MMRI in Yousafwala—with its limited research staff, scant budget, and lack of personnel in the key disciplines of crop management research—to attempt to develop varieties and production practices for the rainfed portions of Punjab that fall within this agroecological zone. Leadership for research in rainfed areas should be determined on the basis of agroecological advantage rather than provincial boundaries.

It is much easier to produce maize in the more benign winter/spring season in central Punjab than in the environmentally severe summer kharif season. If the economics of winter/spring maize cultivation justifies expanded production, some 300,000 ha of irrigated land in central and southern Punjab could be planted to maize in January-February, to produce up to a million tons of additional grain.

Winter/Spring Season Production at the Lower Elevations—The past 20 years have seen the rise of intensive cropping patterns in which the more lucrative kharif-season cotton, basmati rice, or potato cash crops delay rabi season wheat planting (resulting in reduced yields) or induce farmers to simply let the land lie fallow rather than plant wheat It has been estimated that at least 300,000 ha of land suitable for spring maize farming in central Punjab alone are currently unused or poorly utilized, being sown to late-planted wheat in the rabi season (Chaudhry, 1987). While the economics of spring maize production needs further study, especially given the relatively high water cost involved (6-8 irrigations versus 3-4 during the kharif season), in central Punjab spring is a more benign period for maize production than the hot summer season

The number of irrigations and the potential for conflicts with other crops could probably be reduced if spring maize were planted 20-30 days earlier than the current sowing date. Intermediate-to-early maturing varieties with cold tolerance at planting would permit maize planting in January-February, ensuring suitable stand establishment and vegetative growth while winter temperatures still prevail. (Even without cold tolerant materials, Rafhan contract growers obtain average yields of nearly 3 t/ha by planting in February-March and harvesting in May-June, and the top 20% of these growers produce over 4 t/ha).

High-yielding maize populations are available in the research system and have already produced short-season varieties such as Sunheri, New Shaheen, Azam, and Gauher. With a little development work, these populations could be used to produce hybrids well-suited for cotton/maize and rice/maize cropping systems in the lower-elevation irrigated areas, substantially increasing maize production in the near future.

Strategies for Maize Development

Pakistan has made great strides in developing its agricultural sector during the past three decades. Since 1960, the production of wheat, rice, cotton and sugarcane have tripled. These production achievements did not occur by chance. Rather, they are the result of massive investments in irrigation, fertilizer plants, seed production, marketing systems, credit, machinery, and research and extension.

Despite the resource-poor profile of most maize producers in Pakistan and the frequently harsh physical environment in which the crop is grown, important changes also have occurred in maize production technology over the past 20 years. The research system has developed more than a dozen improved genotypes which, when available, have been adopted by farmers (especially in the low- and mid-elevation kharif production zones). Virtually all farmers now use chemical fertilizer on maize, especially nitrogen. Tractors are used extensively for land preparation, and maize shelling operations today are generally mechanized. Finally, the amount of maize entering commercial market channels is increasing as a consequence of expanding demand for maize, particularly as a feed grain and as raw material for industry.

Estimates of Future Maize Demand

Pakistan has identified increased maize productivity and production as one of its agricultural development priorities (PARC, 1986a). Future demand for maize will depend on three principal trends: 1) population growth and its effect on per capita human consumption of maize, 2) green fodder requirements in areas where maize is a primary fodder source, and 3) the use of maize in the poultry feed and wet-milling industries.

The projections for future maize demand put forth in this report are based on the following assumptions: 1) that overall population growth in Pakistan is slowing and urban growth will be considerably higher than rural growth; 2) that per capita maize food consumption will remain constant in rural areas, given the tendency for wheat flour to take the place of maize where the latter is used for human consumption; and 3) that feed and industrial maize demand will slow somewhat compared to the past decade, but will continue to be relatively strong.

With these assumptions in mind, an annual growth in demand for maize of 3.4% is projected for the period from 1985 to the year 2000 (Table 29), based on a 2.6% population growth rate (4.0% urban and 2.0% rural), a 2.0% annual increase in human consumption of maize grain (the rate of estimated growth in rural population), and a 7.0% yearly increase in industrial and feed demand. The latter was determined using a projected 2.9% annual per capita increase in income, an elasticity of demand of 1.5 for maize to supply the industrial and feed markets, and the projected overall population growth rate for the country.

The demand for maize as a poultry feed is expected to increase rapidly during the next several decades, growing at a rate of 7% per year, compared with a 2% rate of growth in demand for maize as a human food. The diffusion of yield-increasing, cost-reducing maize production technologies can lower feed poultry costs, the major expense in egg and meat production.

The projections show direct human consumption declining by the end of the century from approximately 75% to 60% of total utilization and industrial and poultry feed uses increasing from 20% to 35% of total utilization (demand divided in equal proportions). Seed and other uses should stay constant at 5%. (The main industrial use of maize will be to make sweeteners for various food products; this demand will likely increase at a rate similar to the demand for poultry meat and eggs.)

Table 29. Estimates of Maize Demand in Pakistan, 1985-2000

Year	Population (millions)	Human Food	Feed & Industrial	Seed & Waste	Total
		Maize Utilization ('000t)			
1985	95	768	205	51	1,024
1986	98	784	219	54	1,057
1987	100	799	235	55	1,089
1988	103	815	251	57	1,113
1990	108	848	287	60	1,195
1995	123	936	404	71	1,411
2000	140	1,034	565	84	1,683
Growth, (%/year)	2.6	2.0	7.0	3.4	3.4

Source: PARC/CIMMYT Collaborative Program

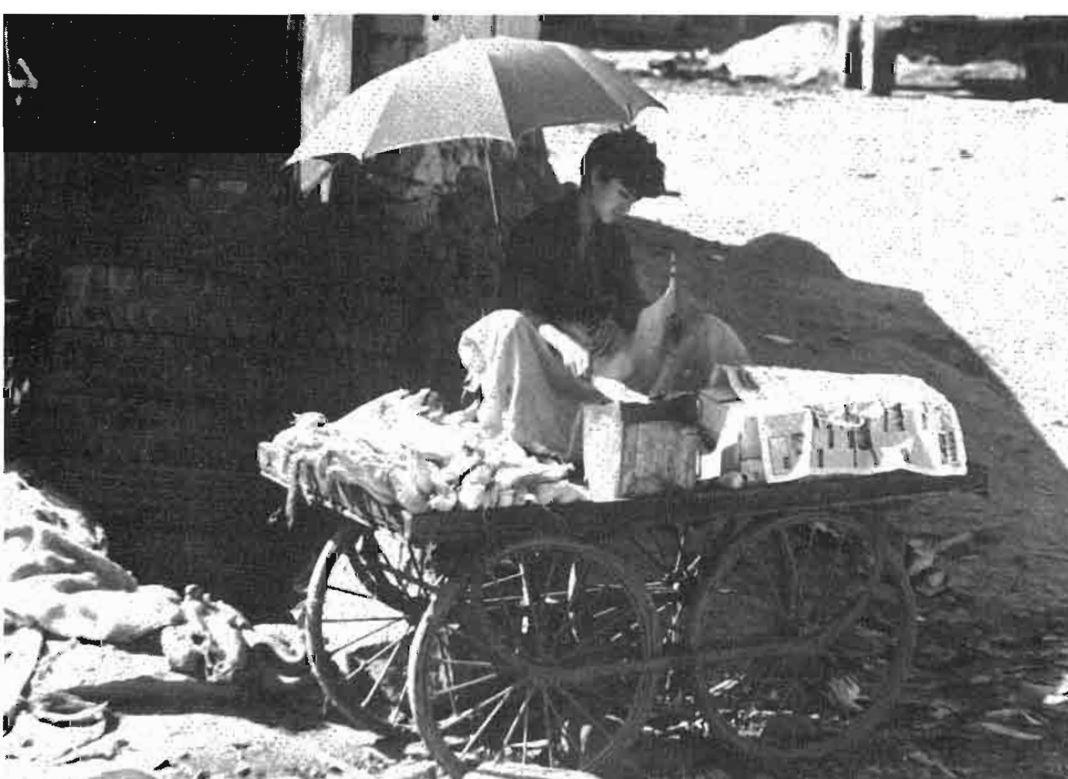
Relatively strong maize grain demand is expected from the wet-milling industry, which is expected to grow at 7% per year, accounting for 15% of national maize utilization by the year 2000. Considerably more maize will be used to produce sweeteners for soft drinks, while the traditional use of grain in wet-milling—starch production—is not expected to increase much faster than population in Pakistan.

Faced with a lack of growth in productivity and relatively high prices for domestic maize, policymakers must weigh the pros and cons of supplying Pakistan's maize demand through domestic production, low-price imports, or a combination of both. The poultry and wet-milling industries, no doubt, would like to purchase their maize in the international market, since they could satisfy their needs at a 20% reduction in price. On the other hand, Pakistan's maize researchers and those farmers who sell their grain surpluses on the commercial market would clearly not like to see the government open the door to lower-cost maize imports.

Traditionally, 75% of all maize grain is consumed as a human food in Pakistan. Per capita food demand, however, is not expected to grow in future years and will largely be met through subsistence production. The demand for maize in the commercial markets will be mainly for industrial and poultry feed puproses. For potential maize demand to materialize in these markets, farmers must adopt yield-increasing, cost-reducing maize technologies.

Accelerating Maize Productivity Gains

During the past 20 years, maize production in Pakistan increased at an average rate of about 3.3% a year, with roughly two-thirds of this growth achieved through area expansions and the remainder through yield improvements. While there appear to be substantial opportunities to expand the area under maize production during the spring season, especially in the Punjab,



such potential area expansions would be countered by net losses in irrigated maize-growing areas of NWFP and Punjab, which are being shifted into higher value crops. It is not likely that the total national maize area can increase at the same rate as in the past. During the next 15 years, growth in yields should play a more dominant role, with yields increasing at a rate similar to population growth and area staying constant or growing very slowly. To meet this objective, national maize yields in Pakistan would have to increase by about 50% by the year 2000. Such an increase is certainly attainable from a technical standpoint.

The Price Incentive Question

The lack of a guaranteed price for maize is frequently cited as a serious constraint to enhanced production and productivity. However, during the three-year period from 1984 to 1986, the average wholesale price of maize in Pakistan was 5-15% above wheat and 20-25% above the world price of maize (landed in Karachi).

This premium appears sufficient to stimulate production (and productivity). Moreover, a 3.2% annual expansion in Pakistan maize area since 1978 suggests that farmers probably agree. NWFP has been the source of this growth (4.5% per year) while maize area in the Punjab has declined. Most of the expansion has occurred in rainfed areas where maize production tends to be precarious. Increasingly, farmers in NWFP with good irrigation are switching to higher-value cash crops such as fruits, tobacco, and sugarcane.

Because the technology transfer system has not operated efficiently for maize, it is still not clear what priority policymakers should give to the crop. Certainly yields could be increased 15% just by supplying farmers with seed of improved genotypes developed by research services. Such a production boost would make maize farming a more profitable operation, as well as lowering its relative price in the marketplace. Growth in the organized maize market could increase price instability unless extensive grain storage and marketing facilities are established.

It will be far easier for policymakers to justify reliance on domestic maize production to meet the national demand if the productivity of resources devoted to this crop can be increased. Though higher prices can stimulate agricultural production, they do not necessarily improve social welfare. For this to happen, price incentives must be accompanied by the adoption of yield-increasing, cost-reducing technologies. In this way, producers benefit because of increased productivity and consumers benefit because of increased supplies and lower real prices.

Development of the Maize Seed Sector

In a cross-pollinating crop such as maize, only limited returns will be realized from investments in plant research if a functioning maize seed sector is absent. This is clearly the case in Pakistan, where a non-functioning maize seed sector has had enormous social costs in terms of foregone productivity.

The lack of a viable maize seed industry is the single-most important constraint on maize yields in Pakistan today. Pakistani maize research institutions have developed some excellent white- and yellow-grain varieties for use by farmers. These improved open-pollinated varieties have been introduced into most maize areas through various extension demonstration programs. No organized seed industry exists to produce and market certified seed of these high-yielding varieties.

Available Genotypes—Improved maize varieties developed through Pakistani research institutions are available to serve some 650,000 ha of the total maize area. These varieties can probably increase yields by 10-20% with a 5% increase in total production costs, even if no other production practices are changed. Maize hybrids, at various stages of development within the research pipeline, could increase yields on commercial maize farms even further.

The potential for introducing hybrids in the irrigated zones of central Punjab and NWFP is very good. For the mid- and high-elevation rainfed areas, where high seed rates are used to permit thinning for green fodder and where most maize is consumed on the farm, the seed sector focus should be on marketing improved open-pollinated varieties.

Seed Production—Adequate supplies of breeder and pre-basic seed of the open-pollinated varieties and hybrids that are recommended for commercial production must be available and maintained in true-to-type form (Wedderburn and Chatha, 1982). This task is generally the responsibility of the breeder. (One reason seed production programs often fail is because of the inability to maintain the original lines properly.)

Supplies of basic seed also must be available to those individuals and organizations involved in commercial or certified seed production. The required seed multiplication is generally the responsibility of a seed production unit under the supervision of the breeder. If private sector organizations are to be involved in producing varieties and hybrids developed by the public sector, a clear policy on the allocation of breeder and basic seed to public and private organizations will be especially important. Will seed of improved varieties and inbred public lines be available to private seed producers? If so, on what terms and at what price?

In the more remote areas, it may not be economically feasible to develop the normal seed enterprise system. In these cases, one option is to establish farmer seed producer groups. The seed these groups produce need not go through a seed certification program, although new basic or registered seed is periodically needed to keep seed stocks relatively pure. Such groups will need technical assistance in managing seed-increase plots; in some cases, financial help to maintain sufficient inventories will also be needed. Here, the priority would be on open-pollinated varieties and perhaps inter-varietal hybrids at a later stage of development. Both research and extension can contribute to the establishment of this kind of seed producer/seller groups.

Seed Distribution—Most successful seed programs develop large networks of primarily private seed retail dealers throughout the country (China being the major exception). Because it is the dealer who actually carries the message about improved varieties or hybrids to the farmer, special educational programs to ensure dealer knowledge about the characteristics and suitability of available seed products can pay large dividends. Seed distributors can also provide useful feedback to seed producers and breeders about the performance of various commercial materials and about varietal needs not being met by available materials.

Price policy is crucial to the establishment of a viable maize seed sector. Those that produce certified seed must be given sufficient incentives to ensure that they use their best fields and are

Nitrogen fertilizer is commonly used in maize production in Pakistan, although at a lower application rate than with wheat or rice. Little phosphorus is applied in maize production, and soils are increasingly deficient in this essential plant nutrient. A more effective fertilizer distribution system is needed to supply the right kinds and amounts of fertilizer to small-scale maize producers, especially in NWFP and northern Punjab.

conscientious in maintaining the genetic purity of the genotypes they are producing. Good supervision of seed multiplication fields by seed certifying agencies is important in assuring such quality control. Good facilities are needed to process, package, and store certified seed to assure high rates of germination. Finally, seed dealers must receive incentives for stocking sufficient seed of the desired genotypes and engaging in needed sales promotion.

Seed Pricing—At present, Pakistan's maize seed prices are among the lowest in the world (Table 8, page 12). Based on seed prices in developing countries with established maize seed sectors, Pakistan should probably double its current prices for certified seed. Experience has shown that farmers are willing to pay a fair price for quality seed. (A grain-price ratio of about 2.5 to 1 for certified OPV seed and 5 to 1 for double-cross hybrids would provide sufficient incentive to expand the seed sector). As long as prices are kept below actual production and marketing costs, little improved seed will reach farmers.

Private Sector Maize Seed—One recent development in Pakistan has been the growth of the private sector's role in maize seed production. Cargill has been active for the past three years and sales of hybrid seed have picked up dramatically. In addition, Pioneer Hi-Bred International recently announced their intention to invest in a major facility at Sahiwal for producing seed of hybrid maize and of other crops. Such developments indicate a potential for further growth in sales of commercial maize seed to farmers, particularly in the case of hybrids.

A key issue for public sector maize breeders and seed producers is how to respond to the expansion in private sector research and seed production, and the best answer would seem to be a national maize improvement strategy that clearly outlines areas of comparative advantage and, possibly, collaboration. Should the public sector focus on marginal environments because the private sector can most likely conduct research and seed distribution for the favored environments? Should public sector researchers continue to develop open-pollinated varieties for the irrigated valleys and plains? How much support can be provided by the public sector for improving hybrids, and what kind of collaborative arrangements could be made involving, for example, private seed company support for public sector work on inbred lines? These are important matters which will have to be addressed in the coming decade as the private sector maize seed industry grows in Pakistan.

The Seed-Fertilizer Link

Yields on those maize lands that do not receive sufficient quantities of farmyard manure can be substantially increased through greater use of chemical fertilizers. Only two-thirds of maize farmers apply nitrogen and only one-quarter apply phosphorus. Low phosphorus use represents an especially important yield constraint. Although chemical fertilizer use on maize has increased, the proportion of maize farmers using chemical fertilizers and the average dosages applied are considerably lower than is the case for wheat or rice cultivation.

The low application of fertilizer in maize is a function of two factors. The first has to do with availability at the village level of the right kinds of chemical fertilizers, especially phosphatic compounds, which are primarily imported from abroad. Fertilizer shortages are more pronounced in the mid-to-high elevations of NWFP and in the rainfed areas of northern Punjab. Improvements in Pakistan's fertilizer distribution systems are needed so that larger quantities of the appropriate fertilizer nutrients reach maize farmers on time; this development could lead to important gains in maize productivity in future years.

Improved varieties are capable of producing more grain per unit of fertilizer nutrient than do farmers' local varieties. But with little commercial seed of improved maize varieties available in Pakistan, farmers have been reluctant to use more fertilizer. Greater availability of improved maize varieties and hybrids, therefore, should encourage the increased use of chemical fertilizers.

Orientation of Maize Research

Successful maize research and development programs share common elements. First, they must be able to develop superior maize varieties and hybrids and to generate high-yielding technologies that are appropriate in typical farming systems. Second, seed production and distribution systems must be in place so that farmers can obtain quality seed of the appropriate varieties at reasonable prices and in a timely fashion. Finally, the local and national marketing systems for maize must provide sufficient incentives to the farmer for intensifying production.

In the public sector of Pakistan, more than 70 professional researchers are directly engaged in maize research and a similar number probably perform disciplinary research related to maize in some way. Despite this apparently sufficient critical research mass, Pakistan's maize research stations and staffs are quite isolated from the farming sectors they are intended to serve, and scientists remain separated from each other by institutional and disciplinary barriers. Scant operational budgets for inputs, equipment, transportation, and living expenses, along with rigid administrative procedures, have kept researchers largely confined to the research station and out of touch with the maize-growing community

An important contribution of the PARC/CIMMYT Collaborative Program has been its work to expand crop management research and technology verification trials conducted on farmers' fields. Pictured here is Mr. Kiramet Khan, CCRI Maize Agronomist assigned to the lower and upper Swat Valleys. This crop management research program—which looks at maize as both a food and fodder crop and seeks to improve on farmers' practices—has found that current management practices already do a good job of maximizing grain and biomass production.

Under PARC, emphasis has been given to expanding Pakistan's on-farm research activities. Teams of agronomists and economists now utilize on-farm surveys and experimentation to understand the complex cropping systems in which maize is generally grown. They are now seeking to identify and develop production practices that will further increase the contributions of maize production within the overall farming system (PARC,1986b).

Pakistani maize research institutions need to recognize the special operational requirements of on-farm research. First, on-farm researchers need mobility and easy access to funds for operational expenses. Also, because of the difficulty inherent in managing on-farm trials and the frequent dangers of travel, an additional allowance for this type of research is probably merited. How to best integrate on-farm research activities within federal and provincial research programs is still a major management issue facing research leaders.

Strengthening Research Linkages to Production

Pakistan's maize research institutions are not strongly linked with other organizations responsible for promoting maize. Establishing ties between research and production organizations, therefore, is a priority. PARC's Crop Maximization Program (CMP) represents one such potentially effective link. As the outreach arm of the research system, it is charged with demonstrating new production technologies and recommendations to the extension service and other production groups (agricultural credit and input supply organizations). CMPs can also serve as feedback conduits to help various research programs set priorities. Serious attention, therefore, should be given to institutionalizing the CMP concept at both federal and provincial research institutions.

The adaptive research programs of the extension service, if properly focused and organized, can also improve the technology transfer process in maize. Better linkages between maize researchers and agents from ADBP and the Cooperative Bank would facilitate the flow of improved technology by providing needed production credits. Finally, private-sector agro-service companies that engage in custom land preparation and harvesting services could play an expanded role in spreading improved varieties and other inputs and technical advice to maize farmers.

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