THE IMPACT OF DWARF WHEATS ON RESOURCE PRODUCTIVITY IN WEST PAKISTAN'S PUNJAB

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Lawrence W. Witt
Major professor

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ABSTRACT

THE IMPACT OF DWARF WHEATS ON RESOURCE PRODUCTIVITY IN WEST PAKISTAN'S PUNJAB

By

Jerry Bruce Eckert

Dwarf wheat varieties from Mexico were introduced into West Pakistan on a commercial scale in the winter of 1965-66. Since that time the varieties have spread over approximately 70 per cent of West Pakistan's irrigated wheat land. Dwarf wheats are highly responsive to fertilizer, resist lodging and produce yields that are several-fold larger than those of indigenous wheats.

Rapid change in several aspects of wheat production followed the adoption of the Mexican imports. The rapidity of change placed new and severe stresses on agricultural price policy. Policy makers, however, lacked a firm understanding of the changes being wrought within the production environment of individual farmers and were unable to make the necessary policy adjustments with precision.

This thesis attempts to quantify the differences in marginal productivity of farm resources when used to grow dwarf wheats as opposed to native wheats. Detailed sampling of

Punjabi wheat farmers during the 1968-69 season provided the raw data. Cobb-Douglas type production functions were estimated using identical constructions for both wheat varieties. The resulting production elasticities are tested for significant differences and where possible applied to several current policy questions.

Independent variables used included: bullock labor in land preparation, seeding rate, number of irrigations, pounds of nitrogen, pounds of phosphate and pounds of farmyard manure. In addition, zero-one variables were used to identify the effect on yields of different dates and methods of sowing and the possible bias resulting when farmers responded to someone they thought might use their answers against them.

The sample permitted useful conclusions only in the cases of water and nitrogen inputs. Dwarf wheats appeared to be highly responsive to water inputs while no response could be measured for native wheats at an acceptable level of significance. The implications of this differential are traced for adoption patterns, pricing of water supplies and on incentives to overinvest in tubewell installation.

Dwarf wheats were found to be approximately twice as responsive to nitrogen inputs as were native varieties. The implications of this conclusion were developed for fertilizer pricing and subsidizing and the wheat support price level. A suggested framework is presented to adjust these two price variables to attain a predetermined quantity of wheat production.

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By

Jerry Bruce Eckert

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Any well done dissertation contains much of the substance of its author. And that substance is the developmental result of an infinite variety of experiences. Consequently acknowledgment sections must be either woefully inadequate for their task or tediously long. While realizing that many deserving people will be overlooked, this section is of the shorter variety.

The series of teachers, who were at the same time friends and associates, to whom I owe a great intellectual debt, begins with Dr. Morris Kelso of the University of Arizona and continues with Dr. Jimmye Hillman of that institution; Dr. Raymond Seltzer, now with Agri-Research, Inc.; Dr. Bruce Johnston and Dr. Roger Gray of Stanford University and Prof. Dr. Heinrich Niehaus of the University of Bonn. At Michigan State University, Drs. Dale Hathaway, Glenn Johnson, Lester Manderscheid and Lawrence Witt must be cited. The inspiration and personal attention of each of these men is deeply appreciated. Each had a substantial impact in the moulding of Jerry Eckert. Particular thanks are due to Dr. Witt who first guided me in a difficult decision in 1962 and has continued to do so, often beyond the normal call of duty, to this day. The opportunity to come to Pakistan and all that resulted from it I owe to him.

Michigan State University and its Agricultural Experiment Station enabled me to pursue my studies while employed as a Research Assistant. And had the Ford Foundation in Pakistan not considered the results of this study of interest to their agricultural programs, this research would not have been completed. Mr. Robert Havener's encouragement and constructive suggestions in this regard have substantially enhanced the end product.

To my parents I owe a great deal, including most of my education and my total commitment to an international involvement.

To my wife, Sue, thanks for the constant encouragement and for relieving me of many time consuming chores in the interest of academic concentration. Much of the sweat and worry that went into this document were hers.

Lastly my apologies to Erin and Scotty who went without a father at home so frequently and for so long in order that this thesis might be written. May it not be necessary again!

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CHAPTER I

PROLOGUE

Setting

World awareness of the threat of growing food shortages increased rapidly during the first half of the sixties. This sense of urgency, heightened by crop failures on the Indo-Pakistan subcontinent and in China in 1965 and 1966, culminated in dire predictions of massive famines in the near future.[1] Immediate, coordinated action was felt to be needed on several fronts. As stated by one authority, "the scale, severity, and duration of the world food problem are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it."[2]

Developing countries, where this problem is most acute, lie generally in the tropical and subtropical regions of the earth. Conversely, yield increasing developments in food production have occurred largely as the result of concerted, scientific research and innovation. Many of these varieties and techniques are only marginally applicable to a tropical

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[1] William and Paul Paddock, Famine, 1975! (Boston: Little, Brown and Company, 1967).

[2] President's Science Advisory Committee, The World Food Problem (The White House, May, 1967), I, p. 11.

or subtropical peasant farming milieu.[1] Productive agricultural research on those crops and environments where it was most urgently needed was thus sorely lacking in a time of crisis.

In response, the Ford and Rockefeller Foundations collaborated to establish two international research centers located in developing countries and with the primary purpose of increasing yields of the world's most important food grains. At Los Banos, The Philippines, the International Rice Research Institute (IRRI) began work in 1962. And in Mexico the long standing Rockefeller research programs in corn and wheat were expanded and reorganized into the International Center of Maize and Wheat Improvement (CIMMYT).[2]

The success of both institutes has been unparalleled in its rapidity and significance. Both in wheat and rice a new concept in plant architecture, dwarfness, was evolved which has revolutionized the yielding potential of each crop. Essentially, dwarfness enables the plant to absorb much higher levels of nutrients without lodging from excessive vegetative growth. Short stature is combined with an erect leaf characteristic which minimizes shading of lower leaves and maximizes leaf area exposed to sunlight thus enhancing photosynthesis.

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[1] _Ibid._, p. 20. For a discussion of the limited transferability of genetic technology and the need for indigenous research programs, see John W. Mellor, _The Economics of Agricultural Development_ (Cornell University Press, 1966), p. 268 ff.

[2] Letters of the official title--Centro Internacional de Mejoramiento de Maiz y Trigo.

Yields can be as much as doubled or tripled even under native farming conditions. Coupled with rapid growth in available supplies of fertilizer, water and locally adaptive research and extension programs, these varieties have led West Pakistan to self-sufficiency in wheat and rice in only three years since their widespread introduction was begun.

Dwarf wheats are so far superior to indigenous varieties under West Pakistan's irrigated conditions that farmers appear likely to shift over almost completely in the irrigated areas. Since West Pakistan was only 10 per cent deficient in food-grains in the worst crop year of the last decade,[1] the prospect of doubling wheat yields throughout implies a whole new set of problems facing policymakers and planners. After the import substitution phase, the overriding importance attached to the goal of expanding cereal production dissipates. The dwarf varieties become just another production alternative, even though one whose enhanced productivity must require extensive adjustments in the existing allocation of resources. Price policies must therefore be modified to reflect the new set of priorities after self-sufficiency is attained as well as the new competitive relationships among productive alternatives.

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[1]Estimates for fiscal year 1965-66 show total disappearance for consumption, seed and losses (changes in stocks are not available) of 6.989 million long tons while gross production was 6.416 million long tons. Charles Elkinton and Aziz Sayeed, Agriculture in Pakistan (Prepared by US-AID, Karachi, 1967), p. 189.

Problem

These are primarily economic questions which necessitate an economic assessment of the shift from native to dwarf wheats. This study attempts just such an assessment. It asks the question: Are there measurable differences on farmers' fields in the marginal products yielded to a given input by the two types of wheats, dwarf and tall statured? To answer this question, 115 farmers were interviewed who were growing both wheats. Levels of inputs and the resulting yields were quantified for specific fields. Chapter III discusses the survey in detail. From these data, I have sought in Chapters IV and V to develop a pair of comparable Cobb-Douglas production functions, one for each wheat type. The coefficients derived are used to generate marginal physical products which are then compared to determine the impact on the farm of the transition from native to dwarf varieties. The remaining portions of this thesis apply the technical conclusions to some of the agricultural policy issues facing Pakistan at the onset of the Fourth Five Year Plan (1970).

The results should have a dual use. First, as already mentioned, the possible transition to foodgrain surpluses must bring some basic and far-reaching changes in agricultural policy, particularly those policies concerned with product and input prices and resource allocations. Hopefully, these data and conclusions will be a useful and used foundation for those decisions.

Second, development strategists have come to realize that due to the uncertainty facing the peasant farmer, a new innovation or technology, particularly one that requires cash inputs, must often promise a high rate of annual return before it will be widely adopted. Yet such returns are also of such magnitude that they can be expected to create short term distortions in resource allocation and product mix and an imbalance between supply and demand. This has happened in wheat in West Pakistan. Crops such as the basic foodgrains with low income elasticities and a very high preponderance in local diets often experience the constraint of a slowly expanding demand shortly after a production breakthrough. Examining the transition to dwarf wheats in West Pakistan should provide both the theorists and practitioners of agricultural development an insight into the types of problems that may be expected following the introduction of technology that is sufficiently remunerative to be rapidly adopted.

General Characteristics of West Pakistan's Agriculture

West Pakistan is an area of diversity and contrasts. Ranging from the Himalayan "roof of the world" to below sea level in one of the world's most uninhabitable deserts, the Rann of Kutch, the province includes a very wide range of ecological conditions, cropping patterns and crops.[1]

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[1]Only a brief review can be given here. A more complete treatment may be found in: Government of Pakistan, Report of

In all, the province covers 198 million acres but only 40 million acres are considered "cultivated" in the official data. Seventy-six million are in grazing land and other uncultivated used while 82 million, largely in the loosely administered Tribal Areas, are listed as "unreported." Most of the cultivation occurs in the alluvial plain through which flow the Indus and its tributaries. This area includes much of the former Punjab and portions of the former Sind which lie along the Indus course.

Over the last century the five rivers that give the Punjab its name (literally "five waters")[2] have been developed into the world's largest canal irrigation system. As distributary canals were extended to new areas, progressive farmers from the more populous areas were invited to settle on the land, thus forming the canal colonies. Normally half a square of land (12 1/2 acres) was allocated although one square or more could be obtained for special purposes.[3] Construction of new barrages and colonization continues today gradually to increase the cultivated acreage.

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the Food and Agriculture Commission (Karachi, 1960); Charles M. Elkinton and Aziz Sayeed, Agriculture in Pakistan (Prepared by USAID, Karachi, 1967); Mohammad Hasan Khan, The Role of Agriculture in Economic Development: A Case Study of Pakistan (Wageningen, Holland: Centre for Agricultural Publications and Documentation, 1966); Department of the Army, Area Handbook for Pakistan, DA Pam. No. 550-48 (Washington, D.C., October, 1965).

[2]The Ravi, Chenab, Sutlej, Jhelum and Beas; all tributaries of the Indus. Four flow through West Pakistan at present; the Beas joins the Sutlej while still in India.

[3]For a list of indigenous terms, see Appendix A.

Canals are generally of two types: inundation canals, which depend on seasonal overflow from the rivers; and perennial canals which are fed by deflecting the normal flows of the rivers with elaborate headworks or barrages. The non-perennial canals receive water only six months of the year during the summer period of runoff from the Himalayan snow-pack. Many of the earlier canals were also designed for the less intensive cropping pattern and sparser settlement density of the period and consequently provide adequate water for only a portion of the area they command.[1] Hence, the canal system does not offer a complete water supply, particularly during the winter months.

Supplemental water has historically been obtained from countless thousands of persian wells.[2] In a new development during the present decade, nearly 78,000 tubewells[3] have been installed by private parties and over 8,000 more on government account. Normally of one cusec capacity, they provide assured water for at least 50 acres of most crops and have been a major factor in expanding cropped acreage as well as intensifying the cropping pattern. Finally, the world's largest

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[1]The "command area" of a canal is all of that area which lies downhill from the canal and could theoretically be irrigated from it.

[2]An animal powered wheel lifting water 10 to 25 feet from an open well by means of a continuous chain of buckets.

[3]A small diameter (2"-6") borehole lined with sieves and casing which may be 2-300 feet in depth and is powered by an electric or diesel engine.

earth-fill impoundment, Mangla Dam, has been completed and work is well along on Tarbela Dam. Together they should store some 13.1 million acre feet of active water reserve, greatly enhancing the adequacy of West Pakistan's irrigation system, particularly during the winter season.[1]

One hundred years of water development in the province has created an irrigation system that is the major necessary precursor for an agricultural revolution, and it is largely in these irrigated areas that the present rapid growth is concentrated.

Population is also concentrated on these productive areas and farms are accordingly small and fragmented. Median farm size in West Pakistan is approximately 5.2 acres. Seventy-four per cent of the 4.86 million farmers cultivate an areas of less than 12.5 acres. In fact more than 50 per cent of the entire population of the province depends primarily on farms of less than 12.5 acres for a living.[2]

These small farms remain basically traditional in their resource endowment. Twelve and one half acres is approximately the limit which can be handled effectively by one pair of bullocks plus family labor. It is generally too small to make a a tubewell or tractor remunerative. The few simple tools used

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[1]International Bank for Reconstruction and Development, Program for the Development of Irrigation and Agriculture in West Pakistan, Vol. V (London, May, 1966).

[2]Calculated from: Government of Pakistan, Census of Agriculture, 1960 (Karachi, 1964).

are fashioned by village craftsmen, paid for in produce and are perhaps best viewed, as suggested by Mellor, as the embodiment of labor rather than a capital investment.[1] Only three productive factors are generally used which require cash expense; fertilizer, water and, more recently, improved seed.

Where water is available, crops may be grown during both winter and summer seasons. The 1960 Census of Agriculture estimated a cropping intensity of 121 per cent among wheat growers. Since then, with the increase in supplemental water from tubewells and the incentive prices established for wheat, this figure has been rising.[2] Table 1.1 shows the area devoted to major crops and the yields obtained in the years just before the introduction of dwarf wheats.

Wheat dominates both production and consumption in West Pakistan. Sixty-five per cent of all farms grew wheat in 1960 as compared with only 41, 24 and 18 per cent for fodder, cotton and rice respectively, the next most prevalent crops.[3] On the

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[1] John W. Mellor, "Toward a Theory of Agricultural Development," in Agricultural Development and Economic Growth, edited by Herman M. Southworth and Bruce F. Johnston (Ithaca, N. Y.: Cornell University Press, 1967), p. 37.

[2] For all cropped land in West Pakistan the multiple cropping index has risen from 109 per cent at the time of Partition to 113 per cent in 1965. Asian Development Bank, Asian Agricultural Survey (Seattle: University of Washington Press, 1969).

[3] Government of Pakistan, 1960 Pakistan Census of Agriculture, Vol. II (Karachi: October, 1963).

TABLE 1.1.--Acreage Devoted to Major Crops in West Pakistan and Yield Obtained.
(Six year average, 1960/61 - 1965/66)

Crop	Area (000 acres)	Per cent of Cropped Area[a]	Yield (long tons/acre)
Wheat	12,435	32.78	.33
Rice	3,137	8.27	.37
Gram	2,850	7.51	.22
Bajra (millets)	2,026	5.34	.18
Jowar (sorghum)	1,285	3.39	.19
Maize	1,211	3.19	.41
Barley	447	1.18	.25
Food Crops	23,391	61.66	
Cotton	3,523	9.29	.10(lint)
Sugarcane	1,214	3.09	1.15(gur)
Rape and Mustard (oilseeds)	1,173	3.09	.18
Tobacco	116	0.31	.66
Total	29,417	77.55[b]	

[a] - Total cropped area taken as 37.93 million acres based on the average of 1962/63-1964/65.

[b] - The balance of the cropped area is very largely winter and summer forages for which annual data are not available.

Source: - Central Statistical Office, Statistical Pocket Book of Pakistan, 1966 and 1967 issues (Karachi, 1967 and 1968).

other hand, wheat supplies at least 60 per cent of the caloric content of local diets.[1] It is obvious that the successful introduction of a high-yielding wheat would be expected to affect a vast majority of Pakistanis, either as producers or consumers or both.

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[1]Computed from data in: G. C. Hufbauer, "Cereal Consumption, Production, and Prices in West Pakistan," The Pakistan Development Review (Summer, 1968); National Science Council of Pakistan, Protein Problem of Pakistan (Islamabad, July, 1968); and Directorate of Nutrition Survey and Research, Preliminary Report, West Pakistan Nutrition Survey 1964-66 (Islamabad, 1968).

CHAPTER II

THE ACCELERATED WHEAT IMPROVEMENT PROGRAM IN WEST PAKISTAN[1]

Historical Background

Wheat has been the subject of research in Pakistan for over three quarters of a century.[2] As early as 1893 foreign varieties were being tested for their local adaptability. Beginning with the pure lines isolated from local wheats by the Punjab Board of Agriculture in 1906, a succession of "improved" varieties spread in waves over the land. While each contained some advantage over its predecessor, they were all traditional long stemmed varieties which could not utilize heavy doses of nutrients. Even today it is a mark of pride with some farmers when these varieties are grown well enough to reach five feet in height. For the purpose of this paper they will all be classified as native, or desi, as opposed to dwarf varieties.

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[1]A detailed account is available in a forthcoming special bulletin by Ignacio Narvaez Morales to be published under this same title by CIMMYT.

[2]See for example: Mian Anwar Hussain, Agricultural Research at the Ayub Agricultural Research Institute, Lyallpur (Lahore: Government of West Pakistan, 1964); and Ch. M. A. Aziz, Fifty Years of Agricultural Education and Research at the Punjab Agricultural College and Research Institute, Lyallpur (Lahore: Department of Agriculture, Government of West Pakistan, 1960).

Despite three-quarters of a century of these efforts, the crucial variable, yields, remained essentially static. Whatever increased potential the new varieties might have offered was effectively nullified by increasing salinity and the extension of wheat cultivation to progressively less productive lands. Figure 2.1 shows that the gradual growth in production is almost exclusively due to expanded acreage. Data from two available series are plotted for the Pakistan Punjab from 1931-32 to 1957-58 and for the Province as a whole from Partition until 1966-67. In addition to the correlation of trends in production and acreage, Figure 2.1 shows the dominance of the former Punjab in the wheat acreage and production of the province as a whole, as well as the somewhat higher yields due to the concentration of irrigation.

Neither acreage nor production in either series grew at more than 1.1 per cent per annum. Since Partition in 1947, wheat production has grown particularly slowly, expanding at 0.5 per cent annually. Clearly this was inadequate when population in the province has been estimated to increase at annual rates of as much as 3.5 per cent.[1] The inevitable food grain deficits began to appear in the mid-fifties.

Although agriculture received somewhat more attention in the Second Five-Year Plan (1960-1965), than it had in the First Plan, the emphasis remained on industrial acceleration and

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[1]Lee L. Bean, et al., Population Projections for Pakistan, 1960-2000, Monographs in Economics of Development, No. 17 (Karachi: Pakistan Institute of Development Economics, 1968), p. 14.

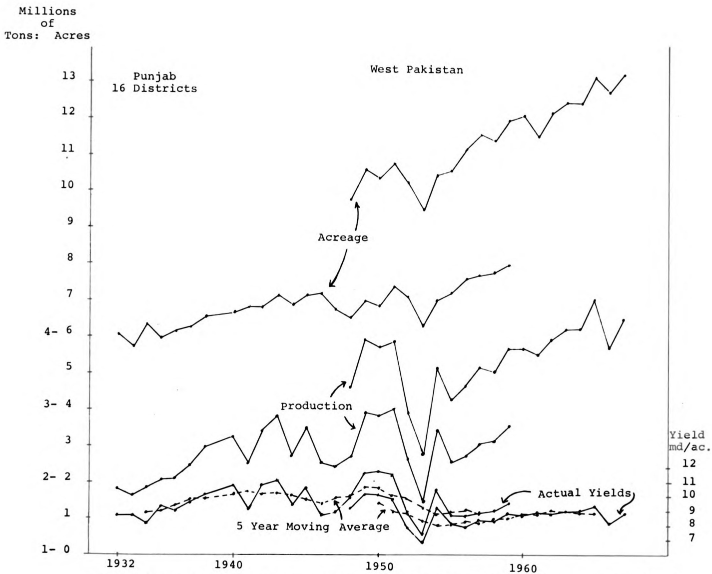

Figure 2.1--Trends in Production, Acreage and Yields of Wheat for West Pakistan and Those Districts Formerly in the Punjab State.

agriculture's share of the overall development program (13.3%) was smaller than four other major sectors.[1] Due largely to surface and ground water development, agricultural growth did rise to a rate of 3.5 per cent annually during the plan period compared with 1.3 per cent per annum for the previous decade.[2] This was, however, only slightly more than sufficient to offset population increases. Food grain imports of approximately 1,000,000 tons continued to be required each year for West Pakistan alone.

Conception

Beginning in 1961, the Rockefeller Foundation's wheat research program in Mexico had provided a limited amount of assistance to West Pakistan's wheat program. They had supplied samples of some of the best Mexican varieties for testing under Pakistan's conditions and four Pakistanis had received eight months training in applied techniques of wheat research.

Then in 1964, Mr. Haldore Hanson, Ford Foundation Representative in Pakistan visited the research program in Mexico and returned quite impressed with the potential it held for Pakistan. The combination of his enthusiasm and the earlier contacts with the Mexican program led Malik Khuda Bakhsh, then

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[1] Planning Commission, The Second Five-Year Plan (1960-65) (Karachi: Government of Pakistan, 1966), p. 12.

[2] Planning Commission, The Third Five-Year Plan (1965-70) (Karachi: Government of Pakistan, 1965), p. 2.

Secretary of Agriculture, Government of West Pakistan, to explore the possibilities of an expanded collaboration with Ford and Mexico. Mexico had shown a greater increase in its average wheat yields than any other country during the preceding decade. Drawing on the Mexican experience seemed perhaps the only way of achieving Pakistan's goal of doubling wheat yields during the Third and Fourth Five-Year Plans, 1965-75.

Dr. Ignacio Narvaez of the Mexican National Agricultural Research Institute visited Pakistan twice during the winter season of 1964-65 to prepare a comprehensive evaluation of the country's wheat research program.[1] In the experimental Mexican wheats then under adaptive testing programs in Pakistan, he saw the potential solution to Pakistan's chronic deficits.

Malik Khuda Bakhsh then requested financial assistance from the Ford Foundation to support the cooperation between Mexico and West Pakistan.[2] Under the accelerated program designed by Narvaez, the Government of West Pakistan agreed to:

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[1]Ignacio Narvaez, "Accelerated Wheat Improvement Program for Pakistan", Memo to Mr. Haldore Hanson, Ford Foundation Representative in Pakistan (Karachi, November 18, 1964), and Ignacio Narvaez, "Accelerated Wheat Improvement Program in West Pakistan," Memo to the Secretary of Agriculgure, Government of West Pakistan (Lahore, March 30, 1965).

[2]Malik Khuda Bakhsh, "Accelerated Wheat Improvement in West Pakistan," letter D. O. No. V-ER(71)DDPAI/64, to Mr. Haldore Hanson, (Lahore, May 20, 1965).

1. Provide all recurring local currency costs of the research in Pakistan. This was essentially a commitment to double annual expenditures on wheat research from rupees 150,000 to 300,000.
2. Take necessary administrative measures to accelerate the work of the Agricultural Research Service with respect to wheat, to facilitate communication between its scattered units and to maintain high morale.

For its part CIMMYT agreed to administer the Mexican participation in the program and to:

1. Release a senior Mexican scientist to serve as resident consultant to the project in Pakistan.
2. Recruit other short-term consultants as needed and agreed upon.
3. Permit export of the most advanced seed stocks emerging from CIMMTY's breeding program.
4. Provide training facilities for Pakistani scientists at Mexican research institutions.

Ford Foundation agreed to cover foreign exchange costs of this project including:

1. Resident technical consultant.
2. Short-term consultants.
3. Project equipment.
4. Travel and study awards.
5. Shipment costs of experimental seed.

The Foundation's initial grant for $300,000 was made in 1965 to CIMMTY which then provided the scientific and technical administration for the program and dispatched Dr. Narvaez as the first wheat advisor.[1]

Objectives

As its basic goal, the Accelerated Wheat Improvement Program sought to accelerate agricultural research so as to generate a rapid rise in commercial wheat production. Wheat research in Pakistan was finally to be put to the test of yield increases under farm conditions. The primary focus of effort was on a breeding program to develop new high yielding varieties based on a blend of the genetic advances made in Mexico with the desirable characteristics of the indigenous wheats. The desired outcome was a dwarf, stiff-strawed, widely adaptable variety that would be highly responsive to fertilizer and yet contain inherent resistance to the diseases and climatic vagaries of Pakistan. An eating quality acceptable to Pakistanis was also sought. Innovative within the Pakistan context was the incorporation of broad agronomic and economic research to develop the accompanying package of cultural practices which would be most suitable to various parts of the country.[2]

Team research was stressed both within and between agricultural research institutes. Scientists from related

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[1] Narvaez, op. cit., March 30, 1965, pp. 3-4.

[2] Ibid., pp. 1-2.

disciplines were to be brought into the design, conduct and evaluation of experiments wherever appropriate. The cereal botanists from each participating institute were to meet together with the resident advisor and other to plan annual breeding and testing programs of maximum complementarity.

It was realized that eventually wheat research in Pakistan would have to mature into a self-sustaining program, run by Pakistanis without foreign advisors or assistance. Consequently, the major portion of Ford Foundation assistance in all three wheat grants to date has been for manpower development overseas. In his progress report of 1965, Borlaug told Pakistan and Ford, "I regard this continuous staff improvement of your research personnel at all levels--the research assistants, senior scientists and the administrators who head the stations--to be the heart of your drive for accelerated wheat research."[1] Accordingly plans were made to send, over a five year period, 30 research assistants to Mexico for one year of applied training under scientists from CIMMYT and elsewhere. Five senior scientists were to receive Ph.D. degrees in aspects of wheat breeding, and each supervising cereal botanist was to make a one or two months study tour of Mexico.[2] Subsequently

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[1]Norman E. Borlaug, "Progress Report on the Accelerated Wheat Improvement Program in West Pakistan," Karachi, November, 1965, p. 14. (mimeographed)

[2]S. A. Qureshi and Ignacio Narvaez, "Annual Technical Report, Accelerated Wheat Improvement Program West Pakistan, 1965-66," Lahore, August, 1966, pp. v-vi. (mimeographed)

this list was expanded further to include advanced graduate training for related disciplines which would contribute to a balanced overall research program.[1]

Implicit in the overall goal was a commitment to enhance the adoption and spread of the results of this research. Among the devices intended to accomplish this within the research program were a series of Micro-Plot Trials and Semi-Commercial Trials of promising advanced lines. These trials were conducted on the fields of cooperating farmers throughout the province. In addition to generating research data, they served to multiply seed and demonstrate its dramatic superiority. Widespread insertion of selected varieties into farmers' hands was achieved by allowing cooperators to keep the seed from the Semi-Commercial Trials after they had seen its yield when grown next to their own desi wheat.

Attainments

The first results of preliminary yield trials in Pakistan identified three Mexican varieties as sufficiently superior under local conditions to warrant immediate multiplication and widespread release. Consequently, 200 kilograms composed of Penjamo-62, Lerma Rojo-64 and Sonora-64 were imported in 1964. They were multiplied on the fields of the three main research institutes during the 1964-65 winter. These three varieties

[1] S. A. Qureshi and Ignacio Narvaez, Annual Technical Report Accelerated Wheat Improvement Program West Pakistan, 1966-67, Lahore, July, 1967, p. 81. (mimeographed)

were first grown in large acale by farmers the following year and covered the great bulk of the total dwarf wheat acreage planted in 1965/66 and 1966/67.

At the same time, seed from the CIMMYT experimental line II-8156-IR-2M-4R was being selected and stabilized at the research institutes within the country. A handful of this seed had been brought back from Mexico in 1962 by one of the four Pakistani research assistants who had been studying in CIMMYT. The strain, a cross between Penjamo-62 and Gabo, an Australian wheat, proved exceptionally adapted, was rust resistant and had the desired plant type. However, it was still segregating for color. Reselection in Pakistan produced two stable lines, a white grain named Mexipak-65 and a red grain called Indus-66. To the farmers these two sisters became White Mexipak and Red Mexipak. Both topped all yield trials under a wide range of conditions during the 1965/66 season. In addition to their yield performance, Mexipak White had the grain color preferred by Pakistanis for their <u>chapatis</u> (flat bread) while Penjamo, Sonora and Lerma Rojo were red wheats and made an inferior <u>chapati</u>. With this it was realized that Mexipak would replace the earlier dwarf varieties as rapidly as seed could be made available and intensive multiplication was begun the following year.

Seed Imports

A major strategem of the wheat program as it developed was to rely on imports of seed wheat wherever possible to accelerate the multiplication process. The first such shipment was a purchase of 350 tons of Penjamo and Lerma Rojo in 1965 for which the government paid $100,000 from their foreign exchange resources.

The following year they sought to purchase 100-300 tons of Mexipak seed with US-AID financing; however, only 50 tons could be purchased. This multiplied the available supplies of the variety by 3.5-fold. In 1967, West Pakistan negotiated the largest single purchase of seed in agriculture's history: 41,720 tons of Mexipak-65 and Indus-66 were brought in. The $5,000,000 cost of this purchase also is the largest single financial commitment of any type by the Government of West Pakistan to the accelerated Wheat Improvement Program.

Table 2.1 summarizes the effects of imported seed on the multiplication process. It can be seen that seed imports increased the availability of Penjamo and Lerma Rojo by 20-fold and white and red Mexipak by 28-fold. When one considers that an approximate 40-fold multiplication is possible in one season under good conditions in a large scale multiplication effort, it is obvious that these shipments saved at least one-half year each in the multiplication program.

Adoption Patterns

Differences in the adoption pattern of the two generations of dwarf wheats are also partly shown in Table 2.1. Only 250,000 acres were planted to Penjamo and Lerma Rojo when it first began to have an impact on consumption. This is shown by

TABLE 2.1.--Effects of Seed Import Program on Multiplication of Dwarf Wheats.

	Lerma Rojo and Penjamo					Mexipak-65 and Indus-66				
	Seed on hand (tons)	Seed imports (tons)	Multiplication factor	Theoretically possible acreage @80#/ac[a] (000)	Actual acreage planted (000)	Seed on hand (tons)	Seed imports (tons)	Multiplication factor	Theoretically possible agreage @80#/ac[a] (000)	Actual acreage planted (000)
1965-66	3LR) 18 15PJ	100LR) 350 250PJ	20 times	10	12	-	-	-	-	-
1966-67	14,500	-	-	395	250	20	50	3.5 times	1.9	6.0[b]
1967-68	275,000[c]	-	-	7,500	753	6,000	41,720	8.0 times	1,300	1,632

[a] - Recommended seeding rate for commercial production.

[b] - Seeded at 26 lbs./ac. for maximum multiplication.

[c] - Hypothetical: assumes all of the previous dwarf wheat crop was saved for seed.

the fact that less acreage was planted than was possible under average seeding rates, implying that some of the preceding crop had been consumed. Mexipak-65 and Indus-66, on the other hand, did not appreciably enter consumption until they had spread to well over 1.6 million acres.

Two reasons may be hypothesized. First, Penjamo and Lerma Rojo were the first Mexican dwarf wheats introduced, and they encountered all of the hesitation and skepticism usually expected when farmers discount promised returns for the uncertainty involved in a new technology. Their success rapidly convinced farmers of the profitability of dwarf wheats and led them to a much greater effort to multiply the Mexipak and Indus varieties when they became available. With their reticence overcome, each farmer sought (and often paid very high prices for) a few seers of seed which he treasured and grew through one or two seasons in order to be able to plant his entire acreage.

Second, Mexipak and Indus are visibly better yielders than Penjamo and Lerma Rojo; farmers could see the difference especially with adequately controlled water and high fertility. This fact probably also contributed to the more exhaustive multiplication efforts which kept farmers from eating much of this grain until after the harvest of 1968. The seeds value as an advanced technology was simply too great to allow its use as a consumption item.

Strengthening Wheat Research

One of the intentions that lay behind the Ford Foundation grants to the program was to develop a revitalized wheat research program within Pakistan's existing institutions that could sustain productive research after Foundation support to the accelerated program terminated. They wanted Pakistan to expand and strengthen its wheat research and to reorganize it in several ways so that it might become more productive. Narvaez had recommended from the outset that it would be necessary for the Government of West Pakistan to double their expenditures on wheat research in order to accomplish this.[1]

The basic additional commitment was forthcoming in the form of a scheme for a "Wheat Improvement and Production Project (Microplot Trials of Wheat Varieties in West Pakistan)" which was sanctioned in 1965. The scheme sought to spend Rs. two million over a five year period for the network of microplot trials mentioned earlier. Dual purposes were pursued--to evaluate new varieties under farm conditions and to further the adoption and spread of the best of these varieties. It is interesting that this basic commitment was to a program which was largely extension. Evidently the government and those who advised them had, by this time come to view the immediate problem as one of selecting the most suitable of the available technologies and then rapidly infusing it into West Pakistan's agriculture. Actual expenditures under the "Micro-Plot Trials

[1] Narvaez, "Accelerated Wheat Improvement Program," (March 30, 1965), p. 12.

Scheme" have run somewhat below projected levels with the result that after four years of the scheme's five year life only Rs. 1,122,000 have been spent.

Subsequently, a second scheme was approved for a summer nursery in the mountain areas. By conducting breeding programs there during the summer a second generation of these winter wheats could be obtained each year. Development and multiplication time for advanced lines would accordingly be halved.

The scheme envisioned a one-time expenditure of Rs. 733,000 spread over a five year period with an annual recurring expenditure of Rs. 50,000 after completion of the project. Difficulties in site selection and acquiring land restricted progress under this scheme and little or nothing had actually been spent by the end of 1969. However, it remains an active scheme, and it now appears that it will be fully completed over the next few years.

Wheat Production

There has been dramatic progress in wheat production since the accelerated wheat improvement program began. Physical attainments are shown in Figure 2.2 and Table 2.2.

Expansion of acreage must be carefully interpreted. A strongly rising trend has been evident since the early 1950's when foodgrain deficits became critical. For the period 1947-48 to 1966-67, this trend may be expressed in the following equation where A is thousands of acres planted and T is the number of years beyond 1946-47.

TABLE 2.2.--Recent Changes in Wheat Cultivation in West Pakistan.

Time Period	Total Wheat Acreage (000)	Production (000 T)	Yield (Mds./Ac.)	Dwarf Wheat Acreage (000)	Dwarf as Per cent of Total (%)
1960/61-1964/65	12,316	4,087	8.94	-	-
1965/66	12,738	3,854	8.25	12	0.1
1966/67	13,205	4,266	8.79	256	1.9
1967/68	14,785	6,317	11.62	2,365	16.0
1968/69	15,221	6,513	11.65	5,698	37.4

Data through 1967-68 from Bureau of Statistics, Planning and Development Department Government of West Pakistan, Quarterly Bulletin of Performance Statistics, Vol. 1, No. 1 (Lahore, January, 1969). Data for 1968-69 from "Second Estimate of Wheat Crop for the Year 1968-69," The Gazette of West Pakistan (Lahore, June 27, 1969). Dwarf Wheat Acreage from Table 2.1.

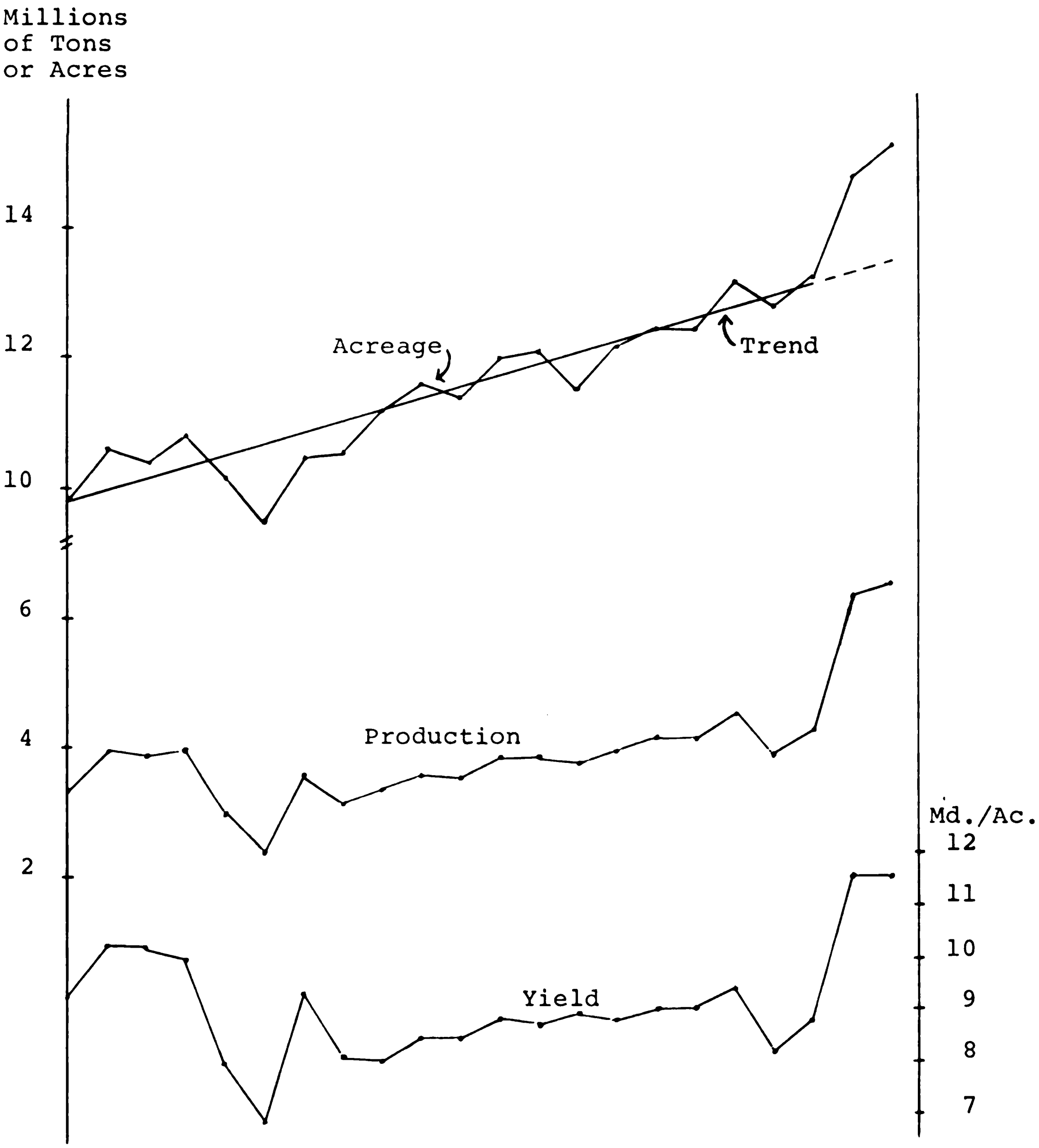

Figure 2.2--Acreage, Production and Yield in West Pakistan Before and After Dwarf Wheats.

$$A = 9555 + 175\ T \quad (R^2 = .86)$$

This trend is superimposed on Figure 2.2.

The acreages for 1965-66 and 1966-67 followed the pattern quite closely. The forecast acreage for 1967-68 would have been 13.230 million acres (95% C.I. = 12.232 - 14.228). Obviously, acreage was significantly higher than the trend alone would have suggested.

Three factors probably contributed. First on April 1, 1967, the support price for wheat was raised from 14.50 to 17.00 rupees per maund.[1] Since the 1966-67 harvest had already begun, this announcement had no effect on acreage for that year. Furthermore, wheat prices remained above the support level for most of the harvest period and the Food Department procured only 21,700 tons.[2] Consequently, when the 1967-68 crop was planted there was no reason to doubt that the higher support price would effectively guarantee profitable cultivation of wheat. Part of the extra acreage may have been in response to this more certain expected return.

Second, the 1967 planting was the first time dwarf wheats were available to a significant portion of the province's farmers.

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[1]Anonymous, "Review of Pricing Police Including Subsidies and Support Prices," Agricultural Wing, Ministry of Agriculture and Works (Islamabad: Government of Pakistan, 1969), p. 2. (mimeographed)

[2]Government of West Pakistan, Quarterly Bulletin of Performance Statistics, Vol. I, No. 1 (Lahore: Planning and Development Board, 1969), Table 34.

The increased profits promised by dwarf wheat probably led many of the more progressive to expand their wheat acreage at the expense of other winter crops or fallow. To most of the small farmers dwarf wheats were an experiment, to verify under their own conditions the reports they had heard of the varieties' excellence. And as with any risk situation there must have been some discounting of expected returns. Therefore, while they may have grown some dwarf wheat, they did not reduce desi acreage by an equivalent amount and thus increased total wheat planted.

This probably happened again in 1968-69 as perhaps one million additional farmers tried dwarfs for the first time. Data from the survey reported in depth below showed that for every added acre of dwarf wheat only .672 acres were withdrawn from desi wheats with the result that total acreage increased by some 19 per cent.

The third probable contributor to the acreage jump in 1967-68 was the favorable weather during the season. Barani wheat requires the residual moisture from precipitation for adequate germination, emergence and seedling development. During planting (October-December) a series of intermittent rains occurred over much of West Pakistan's wheat area. Each one enabled farmers to plow and plant additional acreage. Even in the irrigated areas the phenomenon was observed. Here farmers usually plant wheat and fodder on those acres which they expect normal canal flows and tubewell water to supply. Their remaining acres are left fallow or planted to oilseeds and gram, both of which require very little water. Yet as each additional rain raised soil moisture, many of these acres were planted with wheat instead. These later plantings were then grown under near barani conditions.

Acreage rose even further in 1968-69 in spite of several changes from the situation a year earlier. Only limited rains fell at planting, and they were particularly scarce in the irrigated areas. Also, under pressure from the large crop harvested the year before, the price of wheat actually received by farmers fell as much as 2-2.50 rupees below the support price. Hence most farmers could not realistically count on the profit levels promised by the 17 rupee support price.

On the other hand, a prolonged cool period with frequent rains occurred in the spring of the 1967-68 crop which enabled maximum development of the wheat plant. With the longer growing season, additional carbohydrates were formed which became more grain at harvest. Consequently, the yield potential of dwarf wheat was amply demonstrated to farmers throughout the province. In fact the demonstration may have been misinterpreted overoptimistically since some farmers made commitments of land or capital the following season that would not be justified except in an extraordinary year.

The more important variable, yields, has also shown a dramatic upward shift due, just as with acreage, to a combination of factors. Among them are the spread of dwarf varieties, rapidly expanding fertilizer consumption, above "normal" water supplies in the last two years and an increasing understanding of modern cultural practices.

The spread of the varieties has been enumerated in Tables 2.1 and 2.2 above. Benefits from the variety alone would have been minimal at best. Under reasonable water availability and no fertilizer, Mexipak has been shown to outyield desi varieties by approximately 20 per cent.[1] With this small differential alone, a provincial yield of 12.81 maunds per acre compared to the recent historical average of 8.9 maunds would have been unlikely even if the country were completely covered with Mexipak. Furthermore it is doubtful if farmers would have shifted varieties nearly as far as they have in response to a mere 20 per cent differential.

Dwarf wheats express their superiority in response to high nutrition, and as such the program was the catalyst for strong growth in fertilizer usage.

Realizing the potential, a few persons connected with the wheat program campaigned vigorously within the planning and finance agencies of the government for greatly increased supplies of chemical fertilizer. Their success is shown by the growth pattern in usage since 1965. It should be pointed out that even with an expansion of 60 per cent per year, it has been supply, and not demand that has been the effective

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[1] Z. A. Munshi, et al., "Annual Technical Report, Accelerated Wheat Improvement Program, West Pakistan, 1967-68," (Lahore, July, 1968), p. 30. (mimeographed)

constraint. What has been made available has often been sold at black market prices.

TABLE 2.3.--Use of Chemical Fertilizer in West Pakistan.
(00-T Ammonium Sulphate Equivalent)

Year	Tonnage	% Change	Year	Tonnage	% Change
1952-53	5		1961-62	179	20
1953-54	72	1340	1962-63	197	10
1954-55	69	- 4	1963-64	325	65
1955-56	32	-54	1964-65	405	25
1956-57	44	38	1965-66	335[a]	-17
1957-58	80	82	1966-67	549	64
1958-59	88	10	1967-68	919	67
1959-60	92	5	1968-69	1183	29
1960-61	149	38			

[a] - Supplies curtailed by Indo-Pakistan war.

Source: West Pakistan Agricultural Development Corporation, "The Demand for Fertilizer in West Pakistan" (Lahore: December, 1968).

Some argue that the growth of fertilizer usage should be attributed to the subsidy on fertilizer prices. This certainly was a factor in popularizing its early use, but the most substantial growth has occurred since the dwarf wheats began to spread (1966-67) and in the face of a declining subsidy rate. Furthermore, in 1968-69 many farmers were paying the unsubsidized rate for their nutrients--the 25 per cent black market mark-up nullifying the 25 per cent subsidy. It seems clear that the subsidy is no longer as important a factor in expanding fertilizer use as is the opportunity to use that fertilizer productively and profitably.

A Catalyst for Changing Attitudes

The catalytic effect of the wheat program on the farmers' increasing knowledge of improved cultural practices cannot be overlooked. Recommendations in English and local languages concerning row planting, drilling of seed and fertilizer, placement of seed, planting dates, and proper timing and application of fertilizer and water have been an integral part of efforts to extend the dwarf wheats.[1]

The responsiveness of the varieties to these improvements created the receptive environment in which farmers began to find it worthwhile to change. Seed rates have gradually risen from the traditional 32 seers per acre to nearly 40 on dwarf wheat. Fertilizer application to dwarf wheat has risen to approximately 50 pounds per acre average for the irrigated tracts and its demonstration effect is spilling over into higher fertilization of rice, cotton and sugar cane. The need for phosphorus is beginning to be understood. The $N:P_2O_5$ use ratio jumped from 12:1 in 1967-68 to 6:1 in 1968-69. Domestic industries have begun producing seed drills. Farmers seem increasingly concerned with land leveling to enhance their water use efficiency. A thriving market exists for tractors and combines.

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[1]See for example: S. A. Qureshi and I. Narvaez, "Recommended Cultural Practices for Wheat Cultivation in West Pakistan during the Rabi Season of 1967-68," Lahore, 1967. (mimeographed)

In short, farmers have come to realize that change is not only possible but something to be aggressively pursued. Aresvik has summarized this point as follows:

> In the strategy of agricultural development the improved varieties have to be recognized as the basic catalysts for change. When their performance is spectacular (as with dwarf wheats) when cultivated properly, they take the fancy of the cultivators more than perhaps any other form of new technology. They can be adopted without any great investments in fixed capital and are within reach even for the farmers with relatively small means. They have a high catalytic effect because they require a package of improvements for the high yield potential to be realized. Such a package of improvements can rather easily be introduced together with the new varieties which yield a very high return while this was often nearly impossible--with the traditional varieties.
>
> The success and likely rate of absorption is a function of the difference between the yield capacity and the return of the traditional varieties and the new ones. It is extremely difficult to get the farmers in developing countries interested in small increases--on the other hand, the possibility of doubling or trebling yields--will create interest and enthusiasm, and varieties of this type, according to experience with wheat in Mexico, might spread like a jungle fire.
>
> If the big yield differences are demonstrated spectacularly the 'desire to change' will be lit in the farmers and create receptiveness and a 'spirit of awakening.' This new enthusiasm is an important ingredient in transforming a traditional agriculture.[1]

Enthusiasm was not confined to farmers alone. Faced initially with substantial pessimism on the part of many in the government whose leadership was necessary, the advisor to the program proceeded to plant and grow excellent crops of dwarf wheat on the farms of President Ayub, Secretary and later

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[1]Oddvar Aresvik, "Comments on Hunting Technical Services Limited", 'Memorandum on the Tentative Comments made by the Senior Economic Advisor (Agric.) on LIP Criteria for the Development of Agriculture'" (Lahore, February, 1967), pp. 21-22. (mimeographed)

Minister of Agriculture Malik Khuda Bakhsh and many others. Special efforts were made to have these men visit their fields during harvest and see that 40-50 maunds yields (five times the national average) were truly possible. This simple strategy paid intangible benefits many times over when crucially needed decisions were forthcoming because the policymakers had been convinced of the potential. They had finally seen that rapid agricultural progress was possible and that their own efforts and leadership could be highly productive.

The enthusiasm and energy that was initially spawned by dwarf wheats has conditioned farmers and government officials alike to promote and participate in accelerated programs in rice, maize, sorghum and millets and potatoes. Additional programs following the same lines are planned for pulses and oilseeds.

Significant changes have also been wrung out in the face of some opposition in the organization and conduct of wheat research. These have been amply recorded elsewhere[1] and, being peripheral to this thesis, are not repeated here. It is sufficient commentary to note that Accelerated Crop Improvement Programs as first developed for wheat are being accepted in West Pakistan as one of the basic tools of agricultural progress and the concept is being rapidly expanded to other crops.

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[1] Ignacio Narvaez, "The Accelerated Wheat Improvement Program in West Pakistan," (Lahore, February, 1969), pp. 29-34.

CHAPTER III

THE SURVEY: DESIGN AND IMPLEMENTATION

Dual Purposes Sought

During the winter, wheat growing season of 1968-69 an intensive survey was conducted of 115 wheat growers in Pakistan's central Punjab. Basically the objective was: (1) to quantify the productive differentials believed to be inherent between dwarf and *desi* wheats, and (2) to trace the policy implications for West Pakistan. Success in the latter is predicated upon a substantial measure of success in the former. If, in fact, differential productivities are discovered, these differentials should be brought to bear on agricultural price policy now and for the near future, as long as the current generation of dwarf wheats covers the bulk of West Pakistan's irrigated wheat acreage. Policy implications of these findings form the final chapter of this thesis.

Problems of Survey Research in the Farm Sector of West Pakistan

There are several problems which face a survey of the type done. Some are generic to traditional agriculture, others to foreign countries and some peculiar to the milieu of the Indo-Pakistan subcontinent.

Respondent Apprehension

One of the most subtle, but perhaps most important is the seeming inability to elicit "straight" answers to direct questions. Two social anthropologists, after five years in a subcontinent village, aptly portrayed a typical villagers frame of reference when they wrote:

> Some may call our pretense of poverty, deception. Perhaps it is. But there are times when deception, as a means of self-protection, is justifiable.--There are always hawks hovering about us. We deliberately mislead the inquirer. We would be fools to give accurate figures, when there is a strong probability that they will be used to our disadvantage. In self-protection we have learned to make it almost impossible for anyone to tell who is prospering among us.[1]

This statement was written 30 years ago and while this attitude is gradually changing, elements of it remain, particularly among small farmers who even today are often at the mercy of large landlords, village shop-keepers and minor government officials. As recently as 1967, the Department of Marketing Intelligency and Agricultural Statistics encountered the same problem in their own surveys which they summarized with the statement that, "field staff also faced difficulty in view of conservatism among the farmers because many of

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[1]William and Charlotte Wiser, Behind Mud Walls, 1930-1960 (Berkeley, California: University of California Press, 1963), p. 121.

them were not willing to cooperate as they suspected their replies might put them under more financial burden."[1]

Local apprehension of government officials was indeed felt during the survey. The Pakistani who conducted half of the interviews was carefully instructed to stress that he was working for the Ford Foundation which is a benevolent, non-governmental, private organization interested in helping Pakistan and Pakistani farmers. Nonetheless he was at the same time clean shaven, wearing a clean shirt and pants and polished shoes and thus presumably was initially suspect as an exogenous element in the village scene. In addition, the author, after becoming tanned by the Punjab sun, was, on more than one occasion, initially suspected of being a tehsildar, the man who is responsible for local records, administration and taxes and who in some cases exploits this position to his own advantage.

As an additional precaution, no questions were asked which directly proved the income or asset status of the respondent. Where these data were necessary, they were arrived at by cross compiling questions asked during different interviews or at different points in the same interview.

Analyst's Understanding

As a foreigner in Pakistan, I felt it absolutely necessary to gain as deep an understanding of farming and

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[1]Government of Pakistan, Survey Report on Farm Power, Machinery and Equipment, S.S.-IX (Rawalpindi: Ministry of Agriculture and Works, 1960).

interpersonal relationships at the village level as possible. During the winter of 1967-68, I conducted a brief survey of some 52 farmers on impediments to fertilizer use. This exposure was just sufficient to point out quite clearly that even a great deal of academic training and on-farm experience in Europe and North America does not allow one to easily interpret and analyze the fine points of rural Pakistan. And without a detailed understanding, many of the responses could not be classified as data.

To gain the required interpretive depth, I conducted over half of the interviews myself, traveling nearly 10,000 miles in the Punjab by car, horse cart, bullock cart and on foot and living in villages as the guests of farmers whenever invited. It was, of course, necessary to have an interpreter along. By trial and error the year before Abdul Ghafoor, a driver for the Foundation, had been selected and he served unstintingly as driver, translator and companion through a very rigorous and exacting survey. Ghafoor's assets included thorough fluency in Punjabi and Urdu, the ability quickly to develop a close rapport with respondents, a thorough grounding in agriculture based on his own farming in Kashmir and India, and a wealth of insight into village life and customs.

A, statistical research officer with the Department of Agriculture, was deputed by his government to assist in data collection. Mohammed accepted the job eagerly as a means of broadening his experience and he conducted nearly half of the interviews himself. Like Ghafoor, he had proven himself during the previous survey as being a villager at heart, able to communicate with villagers at their own level and reasonably well versed in agricultural techniques. The frank comments he was able to elicit in informal discussion after the structured questions helped greatly to define the decision milieu within which farmers manage their enterprises.

Language

It should be emphasized that most of the interviews were conducted in colloquial Urdu or Punjabi. This strategy was consciously chosen as a means of minimizing social distance between the two discussants. In the case of the educated, larger farmers, formal Urdu proper or even English was used as seemed most appropriate on the scene.

Recall and Measurement

As in traditional agriculture everywhere, the average West Pakistani farmer does not keep records or accounts for his farm enterprise. Rarely even are cash expenditures recorded or receipts retained. Unless cultural practices are enumerated as they occur they must be recalled from memory. Early cost of production surveys attempted to solve this by placing a resident interviewer in each sample village where he visited his three-six respondents daily.[1] There were, of

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[1]Kartar Singh, Studies in the Cost of Production of Crops in the Punjab, The Board of Economic Inquiry (Lahore: Punjab Publication No. 33, 1934).

course, substantial limits to the number of observations possible using this method. Given the limitations of time and manpower within which this survey operated, the best the present research team could do was to visit each farmer as soon after a given set of cultural practices had occurred as possible.

Recall difficulties are compounded in West Pakistan by multiple cropping and intercropping. Operating without records, the farmer can be expected to recall details of his most recent land preparation, fertilization or irrigation best. With a year-long growing season, one or another of these practices is being applied to one or another crop almost constantly. One cannot wait until the end of the wheat season and then ask for a detailed elaboration of the cultivation techniques and input quantitites applied to wheat. During the wheat growing season Punjabi farmers may also be involved in harvesting, plowing, replanting and fertilizing sugarcane; planting, weeding and spraying tobacco; harvesting rapes and mustards; planting, fertilizing, spraying and harvesting potatoes; irrigating each of these crops plus wheat and clover; and finally preparatory tillage in anticipation of the summer crops. It is not surprising that the time dimension for accurate recall is short indeed.

A related problem is caused by the fact that farm managers often do not deal with their inputs in terms of precisely quantifiable units. Yields, purchased inputs and seeding rate are the exception. Other inputs are less precisely quantified and remembered. Bullocks plow from before sunrise until they quit for one reason or another and the number of plowings that result may or may not be a whole integer. A heap of animal manure is spread on one or more fields until they "look good." One irrigation means the surface of a field all got wet whether that required two or six acre inches of water. Hours spent on a given operation were particularly nebulous. Most small farmers do not have a watch or any reason to need one. Their reference points during the span of a day are daylight and dark plus the various calls to prayer.

There is a tendency to respond with a narrow range as an approximation such as "6-8 hours," 4-5 irrigations or 10-12 plowings. For purposes of calculation the mid-point of each range was taken. For averaging costs the inherent assumption is that the errors thus included are randomly distributed and average out. The computed marginal products may be biased downward somewhat due to errors in measurement of the independent variables even if those variables are randomly distributed.[1] However, in most instances the ranges given were narrow and the resulting bias is probably small.

Vagaries of Nature

Weather often introduces a large element of uncertainty into traditional agriculture. In fact, many of the iron-clad

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[1]M. Ezekiel and K. A. Fox, Methods of Correlation and Regression Analysis (New York: John Wiley & Sons, 1959), p. 313.

production practices which keep traditional agriculture static in the sense of precluding growth have been purposively adopted over the centuries to keep agriculture static in the sense of precluding calamitous natural disaster.

One of the twists of natural fate that affected the 1968-69 crop was an unusual and intense heat wave during the first three weeks of March that sent temperatures into the mid-90's with some readings in excess of 100 degrees. The heat triggered the initiation of the reproductive phase of wheat growth (heading) early, presumably before the vegetative phase had produced and stored sufficient carbohydrates to support abundant grain formation. In addition, evapotranspiration readings indicate that the probability of moisture stress was much higher than usual in a period when there were unavoidable shortages of canal water in many areas. Shriveled grains resulted, and yields were accordingly somewhat reduced. Mexipak, being the higher yielder and thus requiring more carbohydrates, was proportionately more affected. Differences between the native and dwarf varieties were not so pronounced as during the preceding year when cool weather with ample rain lasted until mid-April. Consequently, the marginal product differentials that this thesis seeks will be smaller than might otherwise have been.

In addition, three hail storms swept portions of the Punjab, including two subdivisions of the area under study. One, occurring March 25, was particularly severe with hailstones

reported of over one pound in size, and winds measured in excess of 70 miles per hour. Hardwood trees of two feet in diameter were snapped off six-eight feet above ground and blown as much as 30-40 feet before they struck ground. In the center of devastation much of the ripening wheat was destroyed. Respondents in the sample villages, including 16 farmers who had already been interviewed once or twice, suffered total crop losses and the yields of many other respondents were affected to a lesser extent.

The Right Respondent

When a foreigner enters a village it is quite common for several villagers to cluster around. As one begins to question a selected member of the group, there is a tendency to receive group responses. In villages with a rigid social hierarchy, a low-ranking villager may be very reticent to answer if one of his social superiors is present, or he may give answers designed to be acceptable to this revered (or feared) individual. Even in smaller, family groups there is a tendency for the family elder to respond to the questioner even though his sons did the actual farming. And if the old man approximates an answer wrongly, his sons will usually not embarrass him before a visitor by correcting him. The Department of Marketing Intelligence and Agricultural Statistics makes a similar observation in discussing survey difficulties:

> Generally farmers showed their eagerness to know the purpose of the visit and preferred to answer the questions jointly. The Field Investigators also observed

> that most cases the village headman or local leader was very active to answer the questions on behalf of the selected farmers.[1]

To overcome this we tried to identify the farmer who had actually been involved in the farming operations. Then we insisted on walking out to the sample fields and standing beside them while discussing their cultivation. In most cases this left the bulk of the onlookers, especially village headmen and family elders, behind in their own compounds or verandahs. The interviewees were then basically open and cooperative when alone with us in the field.

Sample Design

District Selection

The Bureau of Statistics conducted a survey of dwarf wheat distribution in 1967-68 in West Pakistan for which they selected eight districts to represent best the irrigated wheat acreage of the province. It seemed appropriate to select a major wheat growing district from one of these for intensive study. It was also desired to select a district where agriculture had begun to change, at least measured in terms of input usage and where dwarf wheat was fairly widespread. By selecting a more advanced district the economic implications for policy from the sample district might have longer relevance as provincial averages of input usage and dwarf wheat

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[1] Government of Pakistan, Department of Marketing Intelligence and Agricultural Statistics (Rawalpindi: Ministry of Agriculture and Works, 1967).

coverage approached and passed through the levels of the sample district.

Table 3.1 presents the relevant criteria on which selection was made. Importance as a wheat producer essentially limited the choice to Multan, Lyallpur and Sahiwal. Lyallpur and Sahiwal ranked equally according to the criteria used. However, Lyallpur is the location of the West Pakistan Agricultural University, the Ayub Agricultural Research Institute and headquarters for the Accelerated Wheat Improvement Program. With this locus of agricultural technology at its hub and with wheat breeders undertaking extension of both techniques and advanced seeds in the surrounding area, Lyallpur was eliminated as not being sufficiently representative. In addition, visual observation in January in the district indicated that native wheats would be very hard to find--a fact confirmed by the subsequent official estimate that the district was 77 per cent dwarf wheat. Multan, in addition to ranking third in progressiveness, had the additional disadvantage that it lay some 200 miles south of Lahore which meant one lost day in transit on each end of each trip.

Sahiwal, the chosen district, is a fairly good example of how the Indus irrigation network changed the face of the Punjab. Before 1915 the area was a desert described by one traveler as "rolling sand dunes patched with grass and hard, unfruitful plains glistening with salt." A major series of link canals completed under the direction of Sir John Benton

TABLE 3.1.--RANKINGS BY SELECTED PROGRESSIVITY CRITERIA FOR WHEAT GROWING DISTRICTS IN BUREAU OF STATISTICS SAMPLE.

District	Wheat Production 1967-68 (000 T)	Dwarf Wheat Percentage (Rank)	Fertilizer Use Per Farm Acre (1967/68) (Rank)	Tubewell Density Dec. 1967 (Rank)	Aggregate Ranking (Rank)
Multan	789	4	3	2	3
Lyallpur	583	1	1	3	1
Sahiwal	582	2	2	1	1
Sargodha	363	5	7	7	7
Muzaffargarh	310	6	8	6	8
Rahimyar Khan	231	8	5	5	6
Sheikhupura	194	3	6	4	4
Nawabshah	147	7	4	N.A.	Ca. 5

in 1917 brought surplus water from the Jhelum river to Sahiwal district through the Chenab and Ravi rivers. The Upper Jhelum canal took water from the Jhelum to the Chenab and irrigated 350,000 acres along the way. The Upper Chenab canal picked up the increased supplies thus added to the Chenab and delivered it to the Ravi, irrigating 650,000 acres in Gujranwala and Sheikhupura districts in the process. The additional Ravi flow thus generated was diverted into the Lower Bari Doab canal and coursed 134 miles southwards changing the heart of Sahiwal and Multan districts from "hard, unfruitful plains" to the breadbasket of the Punjab.

In opening up these very sparsely inhabited areas, colonists were drawn from the best agricultural tribes of the central Punjab. Two objects were paramount. First, colonization officials sought to relieve pressure on some of the more heavily populated areas. Second, they sought to create villages of a type superior to anything seen in the Punjab before. To do so settlers were carefully selected on the basis of character references, village standing and proven farming ability. In addition, preference was given in Sahiwal to those who agreed to enter the production of horses, camels and mules for the army. This early selection process may well have aggregated an energetic population of capable farmers that would partially account for this district being among the most progressive. Massive population movements at the time of partition have altered the mix of racial and ethnic groups in the canal colonies, but it is interesting to note, in the light of Table 3.1, that the colonist selection procedure was most rigorously adhered to in colonizing Lyallpur, Multan and Sahiwal districts.[1]

Sample Frame

Village Selection

For several years the Statistical Department of the Department of Agriculture has conducted an "objective" survey of wheat acreage and production. Their method involves measuring the wheat grown around more than 700 sample villages throughout the province. These villages were selected by a procedure whereby the probability of selection was proportional to the amount of wheat grown by that village. Forty-four of these villages fell in Sahiwal District and thus formed the basic sample frame. One may wonder about the propriety of studying a village that has been repeatedly studied before. However, in several villages I asked about the Statistical Department enumerator and was unable to find a farmer who remembered meeting him. Evidently the enumerator works from the village records kept by the nambardar (village headman) and seldom contacts farmers directly, hence little or no bias could be expected from his visits.

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[1]These and other insights into canal colonies and their farmers during the period 1925-1947 are available in: M. L. Darling, The Punjab Peasant in Prosperity and Debt (Bombay: Oxford University Press, 1947).

Farmer Selection

No suitable lists of farmers could be found from which to draw a sample. Land records could not be used because they reflect ownership only and would have not included tenant farmers. They might also have identified absentee landlords or family members who hold title to the land but do not farm it. Both groups would have been insufficiently familiar with practices and inputs actually applied.

Basically, the selection procedure involved arriving at the sample village and by discussions with one or more responsible villagers, identifying three farmers who fit a set of predetermined selection criteria. These criteria were:

1. Grew both Mexipak and native wheats.
2. Interviewee was actually associated with growing the crop.
3. One out of five to be a farmer of more than 25 acres.

Fulfilling these criteria was not always possible. The most frequent problem was finding anyone who grew desi wheat.[1] In at least one village, one of the local government officials had threatened farmers with a fine for growing desi wheat, so while there was a field or two in evidence, the owners could not be located. Where it was impossible to find enough respondents growing both varieties, growers of Mexipak alone

[1]Subsequent data from the Statistical Department show the district to be 65.12 per cent dwarf wheat, second only to Lyallpur's 77.37 per cent.

were interviewed to add additional observations to that particular set of data.

When one enters a village and asks to see "a wheat farmer" he will quite often be referred to the best known, most progressive farmer in the area. But most of these men had been the first to try dwarf wheats in 1966-67 or 1967-68 and had found them profitable enough to switch completely by the year of the survey. By requiring as many growers of both varieties as possible, we precluded skewing the sample toward these men and instead obtained a fairly good cross section farmers of "average" management capabilities.

Variety Selection

Since Mexipak-65 (White Mexipak) and Indus-66 (Red Mexipak) are genetic sisters except for color, they are treated as one variety in the sample. While initially any dwarf wheat was to be included in the computations, sufficient red or white Mexipak was found to make it unnecessary. Similarly, of the available research data, most would show C-591, C-273 and Dirk to be approximately equal in Sahiwal, and in fact, the farmers grow them interchangeably and without preference. These three varieties are thus assumed to be equivalent in their yield response to inputs and are treated as one traditional variety on which the *desi* production function is to be based.

Production Function Variables

Stress was laid on a precise identification of those variables which were to enter the production function analysis.

The following are used for this purpose:

Water

The number of irrigations applied was asked twice, once when the grain was ripening under the assumption that irrigation had been completed and once after harvest. To our surprise many farmers irrigated once or twice more while the grain was actually turning color. Although the marginal value of these late irrigations is questionable, they are counted along with the rest. There was no way to translate an irrigation into an actual quantity of water applied. Irrigations thus enter the equation as integer units.

Each farmer was asked about rain; however, in almost all cases, the first rain after planting was in conjunction with the March 25th hailstorm and had little effect on production. This was entirely consistent with other data which show that no rainfall is to be expected during a normal wheat season in Sahiwal District.[1]

Chemical Fertilizer

Farmers enumerate their fertilizer applications in terms of "bags per acre" despite the fact that there are nine different quantities of nutrients in the different bags. Furthermore, farmers frequently do not know what fertilizer they have

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[1] International Bank for Reconstruction and Development, Program for the Development of Irrigation and Agriculture in West Pakistan, Annexure 9 - Agriculture, Vol. 7 (London, May, 1966), p. 62.

applied. The bulk of supplies are still imported and the English or German identifications on the bags are meaningless to them. Except for urea, the farmer often calls all chemical fertilizer "guara" which is the name of the plant used for green manure. Identifications such as Ameriki guara, Germany guara, Multani guara are not uncommon. Fortunately, given accurate information on bag weight, price and color, the contents can be positively identified as no two bags have the same combination of these factors. Price was a problem since black marketeering in fertilizer was a particular problem this past winter season. Mark-up margins were observed as high as 25 per cent. Consequently, using Table 3.2 and the assumption that black market mark-up did not exceed 35 per cent, the responses were converted into pounds of nitrogen and phosphate per acre.

Land Preparation

Initially we sought to determine the number of man-hours and the number of bullock-pair-hours that went into preparing and sowing the field. Bullock-pair-hours per acre were quite consistent between the two interviewers. However, differences appeared in the man-hours recorded per acre and in the relationship between man-hours and bullock-pair-hours. The author had used a concept of "essential man-hours" in which the bullock-pair-hours formed the base (since each pair needed a driver) and additional hours were added for those jobs done by a man alone (such as sowing seed, making bunds, etc.). The

TABLE 3.2.--Characteristics of Various Types of Fertilizer Available in West Pakistan on September 15, 1968.

Name of Fertilizer	Nutrients Present: Nitrogen %	Nutrients Present: Phosphate %	Physical Description	Size of bag (lbs.)	Price per bag (Rs.)	Nutrients p/bag (lbs.)
Nitrogen Fertilizers						
1. Ammonium sulphate	21	-	Coarse white crystals	112	11.50	23.5
2. Ammonium nitrate	26	-	White granules	87.5	11.40	23.0
3. Ammonium sulphate	26	-	Large irregular orange granules	110	14.50	29.0
4. Urea (small bag)	46	-	Fine white crystals	50.6	13.00	23.0
5. Urea (medium bag)	46	-	Round white granules	88	20.00	40.5
6. Urea (large bag)	46	-	Round white granules	110	26.00	50.5
Phosphate Fertilizers						
1. Super phosphate	-	16	Greyish white granules	112	9.50	18.0
2. Triple superphosphate	-	46	Round grey granules	110	20.00	50.5
Compound Fertilizers						
1. Nitrophosphate	20	20	Round greyish brown granules	110	21.00	22 lb.N 22 "P_2O_5
2. Di-ammonium phosphate	18	46	Light grey powder	110	28.00	20 lb.N 50.5"P_2O_5

other interviewer enumerated a considerable amount of peripheral man-hours where family members accompanied the farmer to the fields but were essentially unproductive while there. No way could be found to separate this social component after the fact so the two man-hour series could not be made compatible.

The author's enumerations showed a very close correlation between bullock-pair-hours and "essential man-hours." Hence, bullock-pair-hours (BPH) was used as indicative of the total animal and human labor required in field preparation and sowing.

Seeding Rate

Seers of seed per acre were recorded. There was not a great deal of variation with the traditional rate being 30 seers and the recommended rate for dwarfs of 40 seers. Most farmers fell within this range for both varieties.

Farm Yard Manure (FYM)

Farmers commonly apply animal manure to their native wheats as did their forefathers and less frequently apply it to dwarf wheats. Manure, straw and household sweepings are composted for several months either in a pit or in an open stack, and then taken in bullock-carts to the field. There is no common measure of quality. The only quantitative measure which most farmers could recall was the number of bullock-cart loads spread on a given field. These figures were transformed into five maund units using the average reported weight per cartload.

Yield

Of course the dependent variable, yield, was carefully measured. We tried to persuade farmers to thresh the two sample fields each separately and in most cases were successful. However, in cases where the sample field was small and the total wheat of that variety was just enough for one threshing, the sample was sometimes aggregated with other plots. In these cases, the average yield for the lot was taken.

Preliminary analysis indicated that the amount of unexplained variation could be reduced by including zero-one variables in the equation for three items. They were thus included with the following construction:

Interviewer (zero-one)

The respondent's fear of having the information he gives used against him has been discussed above. It is a phenomenon that still exists today. The present survey would indicate it is manifested in different degrees depending on the nationality of the interviewer. Data in Chapter IV show that the Mexican wheat yields reported to Mohammad averaged 19.8 maunds, while those reported to the author averaged 26.2. The Accelerated Wheat Improvement Program estimated Mexican wheat yields for the Province in 1968-69 at 23 maunds. Sahiwal District perennially achieves higher yields than the Province as a whole. Ninety-eight per cent of the wheat land is irrigated and fertilizer is used more intensively. Consequently, with a provincial average dwarf wheat yield of 23 maunds, a figure of

19.8 for Sahiwal District can be labeled as inconsistent while 26.2 maunds would be within the range expected. Hence, it seems that the Mexican wheat yield for Sahiwal District was near that reported to the author. The Pakistani must have elicited depressed responses. The sample district was so selected and subdivided among interviewers that there is no reason to suspect his farmers actually got lower yields.

Another piece of circumstantial evidence has come to light. Farmers in some areas felt the government perceived more of a "Green Revolution" than had actually occurred. They were afraid taxes would be increased by a disproportionate amount. There is some evidence of a tacit agreement among farmers to under-report yields received in 1968-69 to the government even though they readily admitted the true levels to foreigners.

For these reasons it is suggested that the discrepancy between yields reported to the author and to his Pakistani assistant was caused by an under-reporting to the latter. In estimating the production function, a zero-one variable was constructed where it was entered as one if Mohammad interviewed and zero if the author interviewed. The results for this variable should give a measure of the depression of the Y-intercept due to being interviewed by a Pakistani.

This approach implies that the slopes of the production surfaces were not affected. Such a condition holds if one assumes that the understatement was a proportion of the whole (rather than an absolute quantity) and that the proportional understatement was uniform throughout Mohammad's interviews. In this case, the elasticities would be unaffected. Such an assumption is made herein.

Date of Planting (zero-one)

The date of planting was the other variation in technology, the results of which were isolated by zero-one variables. The recommended planting date for Mexipak White, Mexipak Red, C-273, C-591 and Dirk was November 15th. Positive and negative deviations from that date were recorded and coded in two-week intervals. Then the following zero-one variables were constructed:

1. D_2=1 if planted October 26-November 8, inclusive; D_2=0 otherwise
2. D_3=1 if planted November 9-21, inclusive; D_3=0 otherwise
3. D_4=1 if planted November 22 or later; D4=0 otherwise

With this construction, the equation for Mexican wheat was estimated successfully. But, that for native wheats, could not be computed because of a singular matrix problem. Hence, for native wheats D_4 was dropped, leaving the effects of being planted on November 22nd or later in the constant term and D_2 and D_3 measuring deviations from that constant. The omitted term in the Mexican wheat equation is plantation before October 26th. D_2, D_3 and D_4 measure deviations from that date.

The effect of different dates of planting is to vary the stage in the life cycle which the plant is passing through when a given weather event occurs at some future date. The seasonal incidence of rain, heat, wind, and other factors also varies so that the results from any single year have only limited validity in predicting the effect of different planting dates in subsequent years. Nevertheless, treating date of planting explicitly should serve to reduce the unexplained variation in yields during the sample year.

Method of Sowing (zero-one)

The three traditional ways of planting wheat are broadcasting, dribbling the seed by hand behind a native plow (the *kera* method) and dribbling seed into a funnel tube attached to the plow (the *pora* method) which puts seed at a uniform depth, if not a uniform rate. To these, planting with a seed drill has been added in recent years. Among this sample, broadcasting, *kera* and drilling were observed. There were, however, insufficient observations of drilled plantings to justify a separate variable.

Method of sowing was, therefore, divided into two separate techniques, line-sowing and broadcasting. Since broadcasting is the most common, it was desired to measure the difference in intercept that would occur with the conversion to line sowing. A zero-one variable (D_5) was accordingly constructed so that it entered a zero for broadcasting and a one for line-sowing.

Cost Variables

Those variables listed below were collected to determine the cost of production for dwarf and *desi* varieties. Where cost factors were expected to vary for different varieties, they were enumerated separately. Answers were not obtained from all respondents on all points of cost. Therefore, if cost data were available from less than half of the questionnaires, corroborating evidence has been sought elsewhere, and if less than 33 per cent were available, other research was used to provide the cost factor in question.

Cost Item	Brief Explanation
Preparatory plowing and planking	Sum of bullock-pair-hours plus an equivalent amount of man-hours
Bund-making, sowing seed, etc.	Sum of man-hours when bullocks are not involved
Seed	Cost of seed computed in October-November or imputed cost of home produced seed
Animal manure	Imputed cost drawn from other studies
Chemical fertilizer	Value per pound of nutrient at subsidized price
Irrigation costs	Computed separately for each farmer as sum of canal water assessment, plus reported payments for tubewell water. Nothing is added for labor.
Harvesting	Actual reported payments for cutting and binding wheat (usually paid in kind)
Threshing	
a. Bullock labor	Bullock-pair-hours spent to thresh an acre
b. Human labor	Man-hours spent threshing one acre

Winnowing	Since the number of hours varies enormously depending on wind velocity, either the reported payment or the average of the reported payments was used.
Taxes	Total of water assessment and land taxes
Artisans	These are charges incurred in lieu of depreciation on equipment.
Land rent	Actual average land rent for medium quality land adjusted by the reciprocal of the cropping intensity
Miscellaneous expenditure	A small amount of incidentals the amount of which is drawn from other recent studies since it could not be precisely identified using our method

Wheat and straw both have economic value in Pakistan, and herein they are treated as joint products of the same production enterprise. They are assumed to be produced in fixed proportions with a grain:straw ratio of 1:1 for dwarf wheats and 1:1.5 for desi wheats, standard ratios for the two types.

During the 1968-69 harvest, a divergence of prices for both straw and grain became markedly apparent. *Desi* wheat grain commanded a premium of as much as 50 per cent over Mexipak just one month after the harvest was complete. And *desi* straw sold for an average of 66 per cent more than Mexipak straw during the same period because the bullocks and buffaloes preferred the soft straw of native varieties. This is an interesting anomaly since it was precisely to get a short, thick-walled stiff straw that would not lodge that the dwarf varities were developed. In any event, straw and grain of the two varietal types have to be considered differentiated products, each with its own distinct prices, and this has been done in computing per acre return.

Implementation of the Survey

Sahiwal District contains four subdivisions known as *tehsils*. The author and his interviewer each took responsibility for two. Ford Foundation provided transportation for each and the Statistical Department provided directions on how to reach the villages in their sample frame. Thus equipped, the research team was able to negotiate most of the dirt roads. Only in a few cases were horse or bullock carts needed.

Surveyors in Pakistan are often cautioned to get off of the paved road if they want to see how Pakistan really functions. Our villages were often as much as 15-20 miles into the hinterland, all by dirt roads severely rutted by bullock carts. In several villages the author was the first expatriate to visit the village in the memory of any living resident. Our method was to visit each village at least three times. The first round was conducted from December 15th until January 6th, and it was at this visit that we identified the respondent farmers. Questions number 1-43, covering identification, farm characteristics and inputs through the time of sowing, were asked.[1]

With each farmer, the interviewer walked out to one field each of his *desi* and Mexipak wheat and examined the crop in the

[1]The questionnaire is reproduced as Appendix B.

field. The farmer was allowed to choose the field so it is possible that the mix actually examined may have been somewhat superior to the overall average. But by allowing him the choice, it was felt he would indicate fields of which he was reasonably proud and thus more likely to give complete and accurate answers.

The technique of actually inspecting the sample fields each time was a deliberate effort to focus the farmers' attention and recall on that particular field and the exact practices and inputs applied. Deliberate falsification was probably largely avoided as well since the farmer must have assumed that we knew a wheat crop sufficiently well to catch overt misrepresentations of fact concerning the field we were actually inspecting. In the author's opinion, the technique helped greatly to avoid the vague generalizations one often receives when discussing farm practices on the villager's verandah.

The second round occurred during the last three weeks in March at which time emphasis was placed on irrigation and fertilization along with some questions to explore costs. These comprise questions 44-73 in the questionnaire. March, being the growing season, is a slack period and is the time when a number of festivals, fairs and weddings occur. Some of the respondents were away to one of these events at the time of the second visit. If two or more were missing from a given village, the investigators made an appointment and returned within the next few days. If only one man was not available, his answers to questions 44-73 were obtained at the time of harvest.

The third round occurred during the month of June, the Punjab's hottest. Daily highs recorded by the author on each day in the field in June averaged 108.9 degrees. During this period the wheat had been cut, threshed and stored so there was no purpose to be served by walking out to the fields. These interviews were conducted at the man's house, frequently over a cooling glass of loessi, tea or water. This interview covered the inputs and costs associated with harvest and identified the yields received. In addition, if a cursory review of previous questionnaires had revealed discrepancies, these loose ends were resolved in this final interview.

By the third round, we had come to know the respondents quite well. In general they appeared to have become more relaxed, trusting and open with their information. For this reason, some questions dealing with costs, returns and income were postponed until the last visit. It is also felt that the crucial yield data have about as much validity as is possible under Punjabi conditions despite the cautions of many that these are always overstated as a face-saving mechanism.

CHAPTER IV

WHEAT PRODUCTION TECHNOLOGY IN THE PUNJAB
PART I

Structure of the Final Sample

One hundred fifteen farmers were interviewed during round one of the field work. Most of these were again visited during round two before the storm of March 26, 1969. On that date, hail and wind damage effectively removed 16 farmers from consideration by either severe or total destruction of their standing wheat. Two farmers reported no yield due to extreme salinity on the selected fields, another two could not be located during the final visit and four others were lost for miscellaneous reasons. Thus, more than 20 per cent of the original interviewees were lost due to unavoidable causes.

As processing of the data began, answers to several of the questionnaires showed internal inconsistencies. To detect these, several points of cross reference had been built into the questions. Inconsistent answers could have resulted from erroneous interpretation of the question by the farmer, of the response by the interviewer or from deliberate or inadvertent mis-statements of fact. Wherever a misinterpretation was obvious and could be adjusted from other entries or marginal notes, these changes were made. Where this was impossible, the questionnaires were set aside to be used only for their collateral information.

The possibility remained that there had been genuine communicative barriers with some farmers. Some responses were of such extreme values that they suggested a misunderstanding or mis-statement even though they were consistent within the 111 questions asked. Alternatively, accepting that they were factual responses, accurately interpreted then, they suggested a non-typical respondent. And such an outlier, representative of a different "population", by the extremity of his responses would presumably seriously affect the statistics derived.

Accordingly, a computer program was developed to identify outliers objectively. For each observation, the reported values of all Y_i's and X_i's were compared with computed means for each variable. The result was a printout showing, for each variable those farmers that fell beyond the mean ± various multiples of the standard deviation. Those farmers who reported an input level that theoretically belonged to the outlying one per cent of the population (± 2.56 S.D.) were carefully scrutinized. Those who were outliers for more than one production function variable were again discarded. It was felt more likely that they represented errors in communications or deliberate mis-statements than true behavioral deviations. These several screening procedures eliminated an additional 10 farmers leaving only 81, or 70 per cent of the original sample.

This experience suggests caution on the part of future sample researchers in Pakistan. Natural vagaries can arise during the study and eliminate part of the sample in the case where repeated visits are necessary. A cushion of extra observations is thus prudent. Furthermore, difficulty in communications can render some observations unusable. Adequate pretesting of the questionnaire should give an indication of the proportion of rejects to be expected. This, plus a cushion for natural calamity if appropriate, should be factors in determining sample size.

Since comparisons by size of farm are to be made below, it is important to note the distribution of sizes in the final collection of "usable" questionnaires. The discussion that follows will classify farmers cultivating 25 acres or less to be small farmers and everyone else as large farmers. Twenty-five acres is approximately the point at which either a 35 h.p. tractor or a tubewell becomes a profitable investment. It might, therefore, be hypothesized that different input mixes would be found above and below this point.

TABLE 4.1.--Size Distribution of usable Questionnaire.

Acres Cultivated	Sahiwal Sample Distribution (%)	Sahiwal Sample Range (Acres)	West Pakistan No. of Farmers (%)
0-25	70	4- 25	93.1
> 25	30	26-125	6.9

Originally, the sample approximated the actual land distribution more closely. However, all but one of the farmers eliminated by the screening methods outlined above (excluding hail) were small farmers (less than 25 acres) with the result that the distribution shifted toward a more even representation. Perhaps it was fortunate that only small farmers were rejected since it left sufficient observations among the large farmers to estimate the various means for this subset.

Input Levels by Variety

Table 4.2 summarizes the overall average levels of inputs and yields reported for dwarf and native wheats.

Apparently heavier input applications are associated with dwarf wheats. Such an association could result from a conscious attempt to provide better cultural practices for the dwarfs or from the fact that those farmers who practice better techniques were also the early adopters of the dwarf wheats.

To test the significance of the differences between the means, the standard errors of the differences, $s_{\bar{d}}$, were computed using the technique for comparing means of samples with unequal variances.

The statistic $$t' = \frac{d}{s_{\bar{d}}} = \frac{\bar{X}_{1i} - \bar{X}_{2i}}{s_{\bar{d}}}$$

was then derived and compared against tabular values of students t'.[1] The last column of Table 4.2 shows the probability of a Type I error associated with the hypothesis of equal means.

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[1]Using the technique presented in: Robert A. D. Steel and James H. Torrie, Principles and Procedures of Statistics (New York: McGraw Hill Book Company, 1960), pp. 81-82.

TABLE 4.2.--Reported Input Levels for Dwarf and Native Wheats in Sahiwal District.

Input	Dwarf Wheat (n=77) Mean	Dwarf Wheat (n=77) S.D.	Native Wheat (n=66) Mean	Native Wheat (n=66) S.D.	$H_0: X_1 = X_2$ Rejected With Less Than
Date planted (weeks of deviation from Nov. 15)	0.00	1.28	-0.26	1.00	.20
Bullock-pair-hours/acre	46.44	31.89	42.24	27.49	.50
Seed rate (seers/acre)	35.58	4.75	34.23	4.89	.20
Irrigations (number)	7.48	2.08	6.50	2.05	.01
Pounds of nitrogen	49.48	34.21	36.82	33.62	.01
Pounds of phosphate	4.91	15.33	0.67	3.80	.05
FYM (411 lb. units)	5.84	12.23	6.55	10.09	>.50
Yield	22.80	9.76	16.20	5.26	.001

For instance, the difference between average seed rates applied may be read as significant at the 80 per cent confidence level.

Interestingly the average difference reported in yields was more significant than those of any input. This can be taken as one indication of the high yielding potential of the better variety. Approximately one extra irrigation is given to Mexican wheats. Assuming rational farmers, this suggests that dwarf wheats experience a higher response to water supplied than do the desi varieties, a point to be pursued more thoroughly subsequently.

The remainder of those inputs whose application levels were significantly different at the 90 per cent confidence level or greater concerned fertility. Nitrogen and phosphorus are applied in the heavier doses one would expect for a fertilizer responsive variety. The mean values for planting date tell us that on the average Mexican wheats are planted within seven day of November 15th (first week coded 0) and that desi plantings averages a few days earlier.

Input Levels by Farm Size

Table 4.3 shows the average input and yield levels reported by size of farm. Differences in cultivation practices which were significant at the 95 per cent confidence level, appeared only for bullock pair hours spent in land preparation and in seed rate. The larger BPH/acre values among small farmers reflect the substitution of tractor power for bullocks

TABLE 4.3.--Reported Input Levels for Dwarf and Desi Wheats by Farm Size in Sahiwal District.

Input	0-25 Acres		25 Acres		$H_0: \bar{X}_1 = \bar{X}_2$ Rejected With α Less Than
	Mean	S.D.	Mean	S.D.	
Farm Size	14.73	6.84	46.50	1.12	
Dwarf Wheats					
Date Planted	-0.06	1.35	0.12	1.12	>.50
BPH/acre	54.62	31.86	28.38	23.89	.001
Seed rate	34.87	4.86	37.17	4.16	.05
Irrigations	7.62	2.12	7.17	1.97	.40
Nitrogen	48.55	33.38	51.54	36.63	>.50
Phosphate	2.72	11.30	9.75	21.28	.20
FYM	6.91	13.85	3.50	7.23	.20
Yield	22.04	7.95	24.48	12.94	.50
Desi Wheats					
Date planted	-0.28	1.06	-0.21	0.86	>.50
BPH/acre	47.40	29.15	29.47	17.78	.01
Seed rate	33.21	4.69	36.74	4.58	.02
Irrigations	6.68	2.23	6.05	1.47	.20
Nitrogen	36.40	33.84	37.84	33.98	>.50
Phosphate	0.94	4.49	0.00	0.00	.20
FYM	6.81	10.63	5.89	8.84	>.50
Yield	16.54	5.46	15.35	4.78	.40

by larger farmers. Tractor hours are not included in the figures in this table although for the production function analysis an approximate BPH equivalent value was added. In addition, according to an old Punjabi saying, additional plowing always adds fertility. The small farmer with a high labor:land ratio and managing partly by tradition might possibly follow this maxim rather than optimal resource allocation. He might plow until he had very nearly approached (if not crossed) the point of zero marginal product. Instances of 20, 23 and 25 plowings on a single field were noted during the survey, all by smaller farmers. It could also be that a pair of bullocks owned by a small farmer has a lower opportunity cost than a pair owned by a large farmer.

Larger farmers more closely approximated the recommended seeding rate of 40 seers per acre than did their smaller neighbors. This lesson seems to have also carried over to their sowing of native varieties where they were considerably above the traditional rate of 32 seers while the small farmers were not.

Differences in nitrogen application between farm size groups were negligible for both varieties although the differences between varieties are again evident. Phosphate, however, appears on the surface to be an anomaly. Large farmers applied more to Mexican wheats as might have been expected. The only two farmers to apply phosphate to desi wheat were small farmers so the difference appears reversed.

Two interesting and somewhat unexpected results appear in Table 4.3. First, small farmers apply more irrigations to both Mexican and native wheats than do large farmers. One possible explanation is that large farmers with their higher ownership of tubewells are able to apply a more nearly adequate water supply in each irrigation and thus need fewer of them. The small farmer with only canal or purchased tubewell water may tend to cut each field a bit short in order to irrigate as many fields as possible during his turn. In such a case he may actually apply less total water even though his average number of "irrigations" is greater. Unfortunately, as already mentioned, there was no more precise method of quantifying water applications.

Second, while large farmers realized higher yields on Mexipak, they fared somewhat worse than small farmers with the native varieties. No ready answer comes to mind to explain this dichotomy. It should be pointed out that in neither case is the difference in the means very significant.

Input Levels by Interviewer

As the survey progressed, it became apparent that the Pakistani interviewer might be obtaining different answers to some questions. Since both sets of questionnaires were pooled for much of the analysis, it seemed necessary to compare the responses received in each case for significant differences. Table 4.4 presents such a comparison.

TABLE 4.4.--Input Levels Reported to Each Interviewer for Dwarf and Desi Wheats in Sahiwal District.

	Eckert		Mohammad		$H_0: X_1 = X_2$ Rejected with α Less than
	mean	S.D.	mean	S.D.	
			Dwarf Wheats		
Date planted	0.06	1.74	-0.05	0.67	>.50
BPH/ac	48.31	34.42	44.80	29.82	>.50
Seed rate	36.58	4.99	34.71	4.41	.10
Irrigations	6.67	1.90	8.20	1.98	.01
Nitrogen	41.53	32.56	56.46	34.48	.10
Phosphate	8.67	20.42	1.61	7.61	.10
FYM	5.69	11.56	5.98	12.93	>.50
Yield	26.18	10.98	19.83	7.49	.01
			Desi Wheats		
Date planted	0.35	1.38	-0.20	0.65	>.50
BPH/ac	45.65	28.66	40.02	26.84	.50
Seed rate	34.19	4.96	34.25	4.91	>.50
Irrigations	5.19	1.44	7.35	1.94	.001
Nitrogen	18.50	21.12	48.72	35.06	.001
Phosphate	0.00	0.00	1.26	5.18	>.50
FYM	7.08	11.47	6.20	9.21	>.50
Yield	16.24	5.79	16.17	4.96	>.50

For dwarf wheat the differences may be said to be significant at the 99 per cent level for irrigations and yield. Inputs of water and nitrogen to native wheats are significantly different at the same level. In each case, the inputs enumerated by Mohammad are higher while the yields are lower.

The explanation lies in the downward bias in reported yields as a result of being interviewed by a Pakistani which was discussed in Chapter III. Mohammad enumerated water and nitrogen inputs that were moderately higher than the author's enumerations for Mexican wheat and considerably higher for native wheats. Assuming the same proportional depression, Mohammad's reported yields for dwarf wheat could be well below the author's while his *desi* figures, starting from a proportionally higher point, could be approximately equal. Applying a dummy variable for the interviewer will take account of this bias and allow pooling the observations for the production function analysis in the following chapter. To use this technique requires the assumption that each of Mohammad's respondents biased his yield responses downwards by a uniform proportion of the total. The relationship between the variations in inputs and outputs is thus not affected.

CHAPTER V

WHEAT PRODUCTION TECHNOLOGY IN THE PUNJAB PART II

The primary purpose of this thesis was to develop production functions for Mexican and native wheats. Parallel structure in the functions was stressed so that the resulting marginal products could be compared and tested for significant differences. A quantitative assessment of the changes in productivity of the several inputs resulting from a change in wheat variety was the desired outcome.

One qualification is necessary. It was not possible to design the sample so that input levels were held identical between the varieties. In this sense then, the two functions are not strictly parallel. Had input levels not yet begun to shift, then the differences in marginal products would have been the only necessary measure. Instead, the marginal products estimated represent those that prevailed under actual input levels sampled in the winter season of 1968-69. Presumably, a partial adjustment had been made toward maximum profit input levels by growers using the new wheats. A full adjustment to the new equilibrium will, of course, see input usage further changed until marginal value product equals marginal factor cost. If both varieties are still grown at the end of the adjustment period, if inputs are priced equally regardless of where applied and the two varieties are perfect substitutes at a 1:1 ratio in the market (priced identically), then equilibrium will be reached when the marginal physical products are equated. In that case, the appropriate measure would be the differences between input application levels necessary to equate the marginal products. This thesis necessarily presents both differences in application level (Chapter IV) and differences in marginal products with inputs for dwarf wheat adjusted to native wheat input levels.

Table 5.1 summarizes the regression estimates of the two production functions. Analysis of variance for the regression as a whole indicates that for Mexican wheat, the null hypothesis $B_0=B_1= --- =B_n=0$ can be rejected with the probability of a Type I error of three per cent. The coefficient of determination (R^2) was 0.3296 indicating approximately 33 per cent of the sum of squares of the dependent variable can be attributed to the independent variables. For native wheat the probability of a Type I error associated with rejection of the overall null hypothesis was .604, while R^2 was 0.1420. This sample was thus able to show that Mexican wheat yields are significantly responsive to variation in the inputs quantified, but it failed to show such a significant relationship for native wheats. It should be added that the independent variables used represent those inputs over which the farmer has most control. Yield variation in native varieties is apparently more a function of uncontrollable factors.

TABLE 5.1.--Results of the Ordinary Least Squares Regression Estimation of Production Functions for Mexican and Native Wheats.[a]

	Mexican Wheat			Native Wheat		
	Regression Coefficient	Standard Error	Sig.[b]	Regression Coefficient	Standard Error	Sig.[b]
Constant Term	1.86720	0.97385	0.061	1.64683	0.67004	0.017
INPUTS						
Bullock-Pair-Hours	-0.07652	0.07174	0.291	-0.04664	0.06703	0.490
Seers of Seed	-0.62450	0.55512	0.266	-0.28112	0.36734	0.448
Number of Irrigations	0.40318	0.24362	0.104	0.10766	0.20906	0.609
Pounds of Nitrogen	0.07319	0.04084	0.079	0.0377	0.03437	0.277
Pounds of Phosphate	0.00137	0.06105	0.982	-0.02089	0.08951	0.816
Farm Yard Manure[c]	-0.00125	0.04320	0.977	-0.04487	0.03713	0.233
OTHER INFLUENCES (ZERO-ONE VARIABLES)						
Interviewed by Mohammad	-0.18144	0.05895	0.003	-0.03034	0.05188	0.561
Planted 10/26/69-11/8/69	0.15786	0.12493	0.212	-0.11221	0.08305	0.183
Planted 11/9/69-11/21/69	0.19830	0.11610	0.094	-0.06646	0.04750	0.168
Planted 11/22/69-12/12/69	0.15363	0.12216	0.215	See below[d]	-	-
Line Sown	-0.00791	0.05781	0.892	-0.00009	0.05313	0.999

[a] - Geometric means for each of the variable inputs are reproduced in Appendix C.

[b] - Significance. The null hypothesis $b_i=0$ can be rejected with the probability of a Type I error shown in this column.

[c] - Measured in 411 pound units.

[d] - No separate zero-one variable was constructed for native wheats planted on these dates to avoid a singular matrix. The coefficients for the other two dates of planting thus represent yield adjustments from that which would have occurred by being planted during this period.

In an agriculture with a high proportion of subsistence farmers, one of the dominant management goals is avoiding risk.[1] Within this frame of reference, subsistence farmers save and multiply those seeds that show resistance to adverse conditions or inadvertent downward fluctuations in input levels. But production elasticities hold for both decreases and increases. This selection process, therefore, propagates varieties with an inherent insensitivity to upward fluctuations in inputs as well. It should not be surprising that when native wheats have been grown and selected by farmers for 30 years, as have the three in question, they can then be described as not highly responsive to changes in input levels.

Negative coefficients were estimated for bullock labor, seed and farm yard manure applied to both varieties. In addition, yields were negatively related to inputs of phosphate in the case of native wheats. Explanations for a negative relationship are suggested where possible in the separate sections on each input below. Where the functional relationships are truly negative, the Cobb-Douglas functional form is considered inappropriate. The form of the function forces the implication of a total product curve that is positive throughout but negatively sloping at a decreasing rate. Total product thus approaches zero from above asymptotically as X_i approaches

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[1]Clifton R. Wharton, Jr., "Risk, Uncertainty and the Subsistence Farmer: Technological Innovation and Resistance to Change in the Context of Survival" (New York: The Agricultural Development Council, 1968). (mimeographed)

infinity. Both curves are contrary to the accepted theoretical explanations of economic behavior.

Tables 5.4 and 5.5 include, for completeness, calculations of the marginal products for inputs with negative coefficients. Each negative coefficient is examined and then set aside in the separate analytical sections on individual inputs. The negative coefficients are not put to further use.

Zero-One Variables

Of the five zero-one (dummy) variables used for Mexican wheat, all but D_5 for line sowing yielded coefficients that could be accepted as differing from zero at the 75 per cent or higher confidence levels. Four zero-one variables were used for native wheat. The two denoting different planting dates yielded coefficients that differed from zero at the 80 per cent confidence level. The table below shows the contribution made by each in explaining the variation in the dependent variable.

TABLE 5.2.--Changes in the Coefficients of Determination (R^2) Assuming Zero-One Variables Were Not Included.

	R^2 For The Mexican Wheat Equation	R^2 For The Native Wheat Equation
Overall R^2 (None omitted)	0.3296	0.1420
D_1 (Interviewer) Omitted	0.2000	0.1362
D_2 (Planted 10/26-11/8) Omitted	0.3078	0.1107
D_3 (Planted 11/9-11/21) Omitted	0.2897	0.1084
D_4 (Planted 11/22-12/12) Omitted	0.3080	-
D_5 (Line-sowing) Omitted	0.3294	0.1420

D_1 (Interviewer)

This variable contributed more than any other to explaining the variation in yields of dwarf wheat. It was much less helpful, however, in explaining native wheat yields. In fact, the coefficient for this variable could not be accepted as different from zero in the native wheat case due to its large standard error. Under-reporting of yields to a Pakistani national is believed to be the cause as was discussed above.[1] Under-reporting was evidently more severe with the dwarf wheats. At the time of the survey, the "Green Revolution" perceived by many in West Pakistan was largely limited to the adoption of dwarf wheats with their higher yields. It was hypothesized above that farmers tried to minimize their apparent gains in production and income when talking to a Pakistani who might be in a position with government to increase agricultural taxation. To do so would require under-reporting of Mexican wheat yields, not native yields, since the Mexican wheats were considered the embodiment of progress. This hypothesis would seem to be substantiated by the differential under-reporting measured here.

Yields estimated under conditions of being interviewed by the author and his Pakistani assistant are given below. Inputs are held at their respective geometric means and the Y intercept level is adjusted to reflect broadcast sowing within the recommended period (November 15 ± 6 days).

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[1]See Chapter III and Chapter IV.

	Estimated Yields (Md./Ac.)	
	Dwarf Wheat	Desi Wheat
Interviewed by Author	27.12	15.33
Interviewed by Assistant	17.86	14.29

D_2, D_3 and D_4 (Dates of Planting)

Table 5.3 summarizes the results of the zero-one variables for date of planting and line-sowing. The data given are yield estimates derived from the two equations in Table 5.1 under different combinations of techniques.

TABLE 5.3.--Estimated Yields of Wheat Under the Effects of Different Methods and Dates of Planting.[a]

	Broadcast Seed		Sown in Rows	
Date of Planting	Mexican	Native	Mexican	Native
10/12/69-10/25/69	17.18	n.o.[b]	16.87	n.o.[b]
10/26/69-11/8/69	24.71	13.80	24.26	13.79
11/9/69-11/21/69	27.12	15.33	26.63	15.33
11/22/69-12/12/69	24.47	17.86	24.02	17.86

[a]Yields are in maunds per acre holding all inputs at their geometric means and adjusting to the levels associated with having been interviewed by the author.

[b]Not observed. No observations were recorded for this cell.

Each date of planting variable in both equations contributed measurably to explaining the variation in yield. For Mexican wheat, planting within one week of the recommended date (November 15th) did give highest yields in 1968-69. Deviations in either direction brought reductions in yield. Planting in mid-October was the worst of the observed practices, resulting in yield reductions of ten maunds per acre. Wright concludes from experiments in the Indian Punjab that "perhaps one of the worst things you can do to a short duration type wheat is to sow too early. Under these conditions of high temperatures during early growth, the plant does not tiller well and appears to go quickly into the reproductive phase".[1] These estimates support his statement.

Native wheat yields rose progressively the later it was planted in 1968-69. A recommendation to plant on November 15th would have been inappropriate under the particular set of climatic conditions that prevailed that year. It should be emphasized, however, that there is only an imperfect correspondence between weather patterns in any two years. Hence, date of planting variables derived from cross-section data within a single year have limited value in predicting optimum planting dates for subsequent years.

D_5 (Line Sowing)

Line sowing gave virtually no change in native wheat yields and a very slight decrease for dwarf wheats. Both coefficients are statistically very insignificant. The best of them can be accepted as different from zero at the ten per cent confidence level only. Both the coefficients and their negative signs can thus be ignored.

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[1]William G. Wright, "Critical Requirements of New Dwarf Wheat for Maximum Production" (paper presented at the FAO/ Rockefeller Foundation International Seminar on Wheat Improvement and Production, Lyallpur, Pakistan, March 26, 1968), p. 4.

Marginal Physical Products (Actual Input Levels)

Marginal physical products (MPP) were calculated using: $MPP_{x_i} = b_i \ (\hat{Y}/G_{x_i})$ where G_{x_i} is the geometric mean of the observed values for each x_i. The variances of the marginal products, following Heady and Dillon, are obtained by: var. MPP = $\left(\frac{\hat{Y}}{\bar{G}_{x_i}}\right)^2$ var. b_i. This construction requires the assumption that $\hat{Y}$ and G_{x_i} are constants, an assumption that rarely holds for $\hat{Y}$. $\hat{Y}$ is based on values of b_i which are only estimates of true parameters. Since there are variances associated with b_i, so there are also variances associated with $\hat{Y}$ and the variance of any marginal product should theoretically take both into account. Unfortunately, a completely satisfactory statistical technique is not available for this estimation. Heady and Dillon assert that as long as marginal productivities are estimated with inputs at their geometric means, the equation above leads to negligible errors.[1] At this point, the standard error of b_i (and thus $\hat{Y}$) is smallest and $\hat{Y}$ is normally distributed around the geometric mean of Y which for any one sample can be taken as given just as with G_{x_i}. Under these limited circumstances, the required assumption of constancy in $\hat{Y}$ and G_{x_i} does not cause too much methodological discomfort.

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[1]Earl O. Heady and John L. Dillon, Agricultural Production Functions (Ames, Iowa: Iowa State University Press, 1961), p. 231.

TABLE 5.4.--Estimation of the Marginal Physical Products (MPP) From Inputs to Dwarf and Native Wheats.[a]

	Regression Coefficient	Geometric Mean	Estimated Yield (Md./Ac.)	MPP (Maunds)	Variance of MPP
			Mexican Wheat		
Bullock Labor	-0.07652	36.412	27.12	-0.057	0.00286
Seed Rate	-0.62450	35.000	27.12	-0.484	0.18502
Irrigations	0.40318	7.189	27.12	1.521	0.84462
Lbs. of Nitrogen	0.07319	28.371	27.12	0.070	0.00153
Lbs. of Phosphate	0.00139	1.328	27.12	0.028	1.55558
Farm Yard Manure	-0.00125	2.204	27.12	-0.015	0.28314
			Native Wheat		
Bullock Labor	-0.04664	33.475	15.33	-0.021	0.00094
Seed Rate	-0.28113	34.078	15.33	-0.126	0.02731
Irrigations	0.10766	6.166	15.33	0.268	0.27018
Lbs. of Nitrogen	0.03777	14.496	15.33	0.040	0.00132
Lbs. of Phosphate	-0.02089	1.107	15.33	-0.289	1.53611
Farm Yard Manure	-0.04487	2.925	15.33	-0.235	0.03791

[a]Adjusted to conditions of being interviewed by the author, and planted within ± 6 days from November 15, 1968, by the broadcast method.

Table 5.5 compares the marginal products from the preceding table using the test statistic, $t' = \frac{d}{S_d}$, where $S_d = \sqrt{S^2_{MPP_1} + S^2_{MPP_2}}$. Computed values of t' were compared with the tabular values of student's t. Probabilities given here are the smallest tabular probabilities that exceeded the actual probability associated with the computed t'. For example, where $t_{0.3} > t' > t_{0.2}$, the value listed was 0.3 or 30 per cent.

TABLE 5.5.--Approximate Probability Levels for a Type I Error Associated with Rejection of Selected Hypotheses.[a]

Input	$H_O:MPP_m=O$ [b]	$H_O:MPP_n=O$ [b]	$H_O:MPP_m=MPP_n$ [b]
Bullock Pair Hours	0.3	0.5	>0.5
Seed Rate	0.3	0.5	0.5
Irrigations	0.2	>0.5	0.3
Pounds of Nitrogen	0.1	0.3	>0.5
Pounds of Phosphate	>0.5	>0.5	>0.5
Farm Yard Manure	>0.5	0.3	>0.5

[a] In each case the actual probability was somewhat smaller than these levels. These figures are the next largest probability for which a value of students t was given in the source table.

[b] Subscripts m and n refer to Mexican and native wheats respectively.

MPP of Irrigation Water

As mentioned in Chapter III, the most precise available measure of water applied was simply the number of irrigations a field received. "Irrigations" by a native farmer are believed to vary widely between one and six acre-inches of water depending largely on the scarcity of water. Few farmers are familiar with the concept of saturation of the root zone and fewer still have the equipment to measure saturation.

Timing of irrigation _vis a vis_ the growth stages of the plant is a crucial determinant of the productivity of the water applied. Wright has stated:

> Results have shown that the first irrigation given at about the time when crown roots begin to emerge will give highest yields. Under most environmental conditions the tillers begin to differentiate and the crown root or adventitious root system begins to emerge at about 21 to 25 days after sowing. If the soil is not moist at this stage, the crown root system will not develop well and tillering may be reduced. A striking observation in this experiment (in the Indian Punjab) indicated that even with synchronized tillering varieties many tillers will not develop until the first irrigation is given. If this first irrigation is delayed, tillers which develop subsequently may be too late and will not contribute to yield.[1]

Wright also says that "if we are sure to irrigate at about the crown root initiation stage and also during the grain-filling period, it does not make very much difference how we irrigate during the middle period of plant growth so long as the plant does not undergo extreme moisture deficiency."[2]

Unfortunately without farm records, it was not possible to determine _ex post_ when the irrigations had been applied. Many respondents could not even identify precisely the day of the month on which they were being interviewed. Consequently, one has to proceed under the assumption that errors in timing of irrigation are randomly distributed.

The regression coefficient for Mexican wheat was significant at the 90 per cent level, while that for native wheat

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[1]William G. Wright, "Critical Requirements of New Dwarf Wheat," p. 5.

[2]_Ibid._, p. 7.

was significant only at the 39 per cent level. In the latter case, the statement $b_i \neq 0$ has an associated probability of 0.61 of being wrong. One therefore cannot accept b_i for native wheat, nor the marginal product calculated from it.

This comparison confirms the superior responsiveness of dwarf wheat to inputs of water. The difference reflects the different conditions and goals under which the two types were developed as well as the results of 30 years of farmer selection of native varieties in an uncertain and semi-arid environment. Indigenous wheats were developed in West Pakistan with the goal of widespread adaptability to that province's often under-irrigated or rainfed land. Dwarf wheats were bred and selected under fairly adequate rainfall conditions with the goal of maximum responsiveness to inputs, particularly fertilizer.

The sample gave the following estimates for dwarf wheats:[1]

G_{x_i} = 7.19 irrigations	MPP = 1.52 maunds
$\hat{Y}$ = 27.12 maunds	Var. MPP = .845

At the point of G_{x_i}, one irrigation adds 125 pounds per acre to dwarf wheat yields. Table 5.6 presents a schedule of total and marginal products for the range of observed values. The level of one irrigation was not observed, but is included to

[1]Hereafter all estimated yields (Y) are under conditions of broadcast sowing, within ± six days of November 15th, and assuming farmers were interviewed by the author.

approximate the Y intercept value of the curve. All other inputs are held constant at G_{x_i} for these calculations.

TABLE 5.6.--Total and Marginal Product Curves for Water on Mexican Wheat in West Pakistan's Punjab. (in maunds per acre)[a]

No. of Irrigations	Total Product	Marginal Product
1	12.24	4.94
2	16.19	3.26
3	19.07	2.56
4	21.41	2.16
5	23.43	1.89
6	25.22	1.70
7	26.83	1.55
8	28.32	1.43
9	29.69	1.33
10	30.98	1.25
11	32.20	1.18
12	33.35	1.12
13	34.44	1.07
14	35.49	1.02

[a]One maund = 82.286 pounds.

MPP per Pound of Nitrogen

Nitrogen fertilization was the second variable for which positive coefficients were estimated. The coefficients for dwarf and *desi* wheats can be accepted as significantly different from zero at the 90 and 70 per cent confidence levels respectively.

Nitrogen fertilization of wheats has been frequently studied in Pakistan. Yet most, if not all, of the nutrient response studies have dealt with average productivity, ignoring marginal calculations. For this reason they have been of limited usefulness for fertilizer policy.

Marginal physical product estimates from the present equation are summarized immediately below for the point $X_i = G_{x_i}$. Again, all other inputs are held constant at their geometric means.

	G_{x_i}	$\hat{Y}$	MPP	Var. MPP
Dwarf	28.37	27.12	.070	.00153
Desi	14.50	15.33	.040	.00132

These estimates establish the higher fertilizer responsiveness of the dwarf wheats. Even though twice as much nitrogen was applied to them, the marginal product remained 75 per cent above that of native wheat. In terms of pounds of grain returned for one pound of nitrogen applied, the marginal and average grain:nutrient ratios are as follows.

	Average	Marginal
Dwarf	17.0	5.8
Native	8.3	3.3

Specialists with the Accelerated Wheat Improvement Program routinely estimate aggregate production levels for West Pakistan using average grain:nutrient ratios of 16:1 for dwarf wheat and 8:1 for native varieties. The government's "Food Self-Sufficiency Program" used the same ratios in its projections.[1] The results estimated here substantiate these levels and show the difference between MPP and APP. Planning with

[1] Qureshi and Narvaez, "Annual Technical Report, Accelerated Wheat Improvement Program," (July, 1967), p. 39.

only the latter has not provided a firm basis for price adjustments in fertilizer policy.

TABLE 5.7.--Total and Marginal Product Curves for Fertilizer Applied to Mexican and Native Wheats.(in maunds per acre)[a]

	Mexican Wheats		Native Wheats	
Pounds of Nitrogen	Total Product	Marginal Product	Total Product	Marginal Product
1	21.23	1.554	13.86	.523
10	25.12	.184	15.12	.057
20	26.43	.097	15.52	.029
30	27.23	.066	15.76	.019
40	27.82	.051	15.93	.015
50	28.26	.041	16.06	.012
60	28.64	.035	16.17	.010
70	28.97	.030	16.27	.009
80	29.25	.027	16.35	.008
90	29.51	.024	b	b
100	29.73	.022		
110	29.94	.020		
120	30.13	.018		

[a]One maund = 82.286 pounds

[b]Native wheat is seldom fertilized with more than 80 pounds of nitrogen.

Table 5.7 gives estimated total and marginal products for the usually observed fertilization rates holding all other $S_i = G_{x_i}$. One conclusion drawn is that yields much in excess of 30 maunds require very heavy nitrogen in the absence of additional application of complementary inputs such as water and better cultural practices. Many farmers during the 1968-69 and 1969-70 seasons expressed disappointment with Mexipak wheat. It had not given the 40-50 maund yields that they had expected after hearing initial experimental results. Many of those who were disappointed had applied the recommended fertilizer dose of 100 pounds of nitrogen, yet received yields of only 25-35 maunds. Table 5.7 suggests that this was all they could expect without improving several other aspects of their wheat production practices along with fertilization.

Estimates for Bullock Labor

Both of the coefficients estimated for bullock-pair-hour inputs of preparatory labor were negative. Confidence levels were low, 71 and 51 per cent for dwarf and desi wheat, respectively. One is not justified in accepting the native coefficient as significantly different from zero. And the dwarf wheat estimate can be accepted only with limited confidence.

An earlier section of this chapter discussed the difficulty of interpreting negative marginal products within the Cobb-Douglas functional form. Because of the negative coefficient for dwarf wheat and its low significance, no quantitative conclusions will be made about the marginal product.

Recognizing the possibility that multicollinearity among independent variables may cause "incorrect" signs, the matrix of simple correlation coefficients may contain the explanation of the negative estimate. For the Mexican wheat subsample, selected simple correlation coefficients (r) are as follow:

Correlation Coefficients Between	
BPH and Yield	-0.01
BPH and Farm Size	-0.34
Farm Size and Yield	0.05

This suggests that the negative correlation between BPH and farm size was the prevailing factor. Farm size is positively correlated with yield, yet the larger the farm the fewer hours of bullock labor applied. The negative relation to farm size could reflect an inadequacy in the method of pooling tractor plowings (found only on larger farms) and bullock plowings. One tractor plowing per acre was set equal to 5.5 hours of bullock labor, the average time required to plow one acre by this method. A better measure would have dealt with soil tilth and structure but would have required analyses and instrumentation that were not available at the time of the survey. Future work should distinguish sub-samples by tractor and bullock plowing methods in order to better control the influences of each.

The relationships discovered could also be explained by a lower opportunity cost for bullocks on small farms than on large ones. Unfortunately, no data was obtained that would test such a hypothesis.

Estimates for Seed Rate

Negative coefficients were obtained for yield with respect to additional pounds of seed per acre. Confidence levels were low, 73 and 55 per cent for dwarf and *desi* wheats respectively. For the reasons discussed in the section immediately above, no further quantitative statements will be made about marginal productivities.

As with bullock labor, the simple correlation matrix suggests the cause of the negative coefficient for Mexican wheat. Selected coefficients (r) are:

Correlation Coefficients Between

	Mexican	Native
Seed Rate and Irrigations	-0.40	-0.29
Seed Rate and Yield	-0.15	-0.12
Irrigations and Yields	0.36	0.18

In both cases, the highest correlation measured for seed rate was with the amount of water applied and that correlation was negative. Water use, on the other hand, was positively correlated with yield. This suggests that farmers tried to compensate for inadequate water supplies by heavier seeding rates. Evidently, their efforts were only partially successful since with high seed rates and a low number of irrigations, yields were still depressed.

Estimates for Phosphate and Farm Yard Manure

Confidence levels and the signs of the regression coefficients for these two inputs were as follows:

Confidence Levels and Signs ( )

	Phosphate	Farm Yard Manure
Dwarf	0.02,(+)	0.02, (-)
Desi	0.18,(-)	0.77, (-)

Obviously, neither dwarf wheat coefficient can be discussed. For native wheat, the coefficient for farm yard manure is significantly different from zero, but only at the 77 per cent confidence level and it is negative. Again, no marginal product calculations are made.

As might be expected, manure applications are positively correlated with bullock labor use--both reflecting the number of animals per acre. The r value for this relationship is the largest for any involving farm yard manure. Both variables, bullock labor and manure use, are negatively correlated with native wheat yields.

Marginal Physical Products (Adjusted Input Levels)

At the time of the survey, input levels were in transition from optimum levels for desi to optimum levels for the new varieties. The adjustment was incomplete however. A description of the impact of dwarf wheats requires discussion of differences both in the quantities of inputs used, and the marginal products prevailing.

It is of interest to know the differences in marginal productivity that would have prevailed at the traditional input levels associated with desi wheat. Such a calculation gives an estimate of the vertical shift in yield and in marginal product when only the variety is changed.

Despite the negative coefficients for some inputs, the equation in Table 5.1 was used because its coefficient of determination was higher than other available equations. Retaining all six inputs and five zero-one variables gave a better explanation the variation in Y. Results are given only for the water and nitrogen variables.

TABLE 5.8.--Comparison of Native Wheat With Dwarf Wheat Under Two Levels of Input Usage.

	Native Wheat	Mexican Wheat	
	Actual 1968-69 Input Levels	Adjusted Input Levels[a]	Actual 1968-69 Input Levels
Estimated Yield	15.33	24.82	27.12
MPP (Irrigation)	b	1.623	1.521
MPP (Nitrogen)	0.040	0.125	0.070

[a]Input levels adjusted to levels measured for native wheats.

[b]Analysis above shows this figure to be not significantly different from zero.

Adjusting the input levels meant reducing them. As expected, where $b_i > 0$, the marginal products were higher at the reduced levels. Of course, confidence levels increased also as input quantitites were adjusted away from the geometric means at which regression coefficients were estimated.

One important conclusion concerns overall yields. Even without applying more inputs, the simple substitution of dwarf for <u>desi</u> seed increased yields by 9.5 maunds, a growth of 62 per cent. This should not be confused with the usual statement that substituting varieties under unfertilized conditions with four irrigations gives approximately 20 per cent more yield. The 62 per cent identified here is at input levels applied to <u>desi</u> wheats by the sample farmers in 1968-69 and these included a geometric mean of nearly 15 pounds of nitrogen and six irrigations.

The marginal product for nitrogen is three times as large with dwarf wheat as it is with <u>desi</u> under these conditions. It is not surprising then that the transition to dwarf wheats brings with it a strong increase in the demand for nitrogenous fertilizer. Fertilizer consumption was growing at a rate of 34 per cent annually during the five years before dwarf wheats. In the three years since the Accelerated Wheat Program began, fertilizer sales have grown at 52 per cent annually and more would have been purchased had supplies been available.

Finally water applications gave a statistically insignificant marginal product with native wheat. Yet, one irrigation would add 134 pounds of grain in a dwarf wheat field, a marginal product that is significant at the 90 per cent level.

These three figures, the overall yield and the marginal product comparisons for nitrogen and water, establish the superiority of the dwarf wheats in the Punjab. Not only are they more responsive to these inputs, but also the response to any one input occurs within a much higher yield environment.

CHAPTER VI

COSTS OF PRODUCTION

The term "costs of production" is often discussed in Pakistan. Occasionally it occurs in policy discussions covering price support or input subsidy levels for agricultural commodities. More frequently it is heard from farmers or spokesmen for agriculture, often to counter revisions in price policy that have been suggested. The context in which unit cost figures are used is usually one of justifying an adjustment of the terms of trade toward agriculture.

Lewis has observed that "unit costs of production nearly always suggest farmers are producing at a loss." He further points out rather bluntly that "the use of cost of production studies to assess economic advantage in agricultural crops was completely discredited more than 40 years ago."[1]

Witt goes a step further and cites seven reasons why "cost of production studies at best are only a limited guide as to trends in farm costs, and at worst are a confusing morass of conflicting statements on price policy, with pleadings for

[1]J. N. Lewis, "Wheat Marketing in Pakistan and Export Prospects" (memo to Sarshar Ahmad Khan, Lahore, Pakistan, June 30, 1969), pp. 2-3.

special interests."[1] His reasons hinge mainly on valuation problems which even in a developed country are so serious that unit cost calculations are too subjective to be used as a basis for price policy. The problem is compounded in developing countries by poor data, in scarce supply.

Cost of production estimates can be used, however, for inter-varietal comparisons as long as the figures are developed using identical assumptions. Accordingly, costs per maund of wheat were estimated using the same technique for both varieties. A uniform cost per input unit was multiplied by the levels of inputs reported for each variety except for seed where Mexipak and indigenous wheats were valued at 14.00 and 17.00 rupees respectively.[2]

The variables included are listed in Chapter III. The sum of imputed and cash costs was divided by reported yields and used to develop the frequency distributions shown as Figure 6.1. Values were either drawn from survey responses or calculated from other studies according to the criteria specified in Chapter III. Observed distributions are then cumulated into the ogive (cumulative percentage) curves shown in Figure 6.2.

Using data from a single sample and year, with inputs weighted and valued identically, avoids all but one of Witt's

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[1]Lawrence Witt, "Cost of Production and All That" Islamabad, Pakistan, August 8, 1969. (mimeographed)

[2]The price of each wheat at the beginning of November, 1968, when planting commenced.

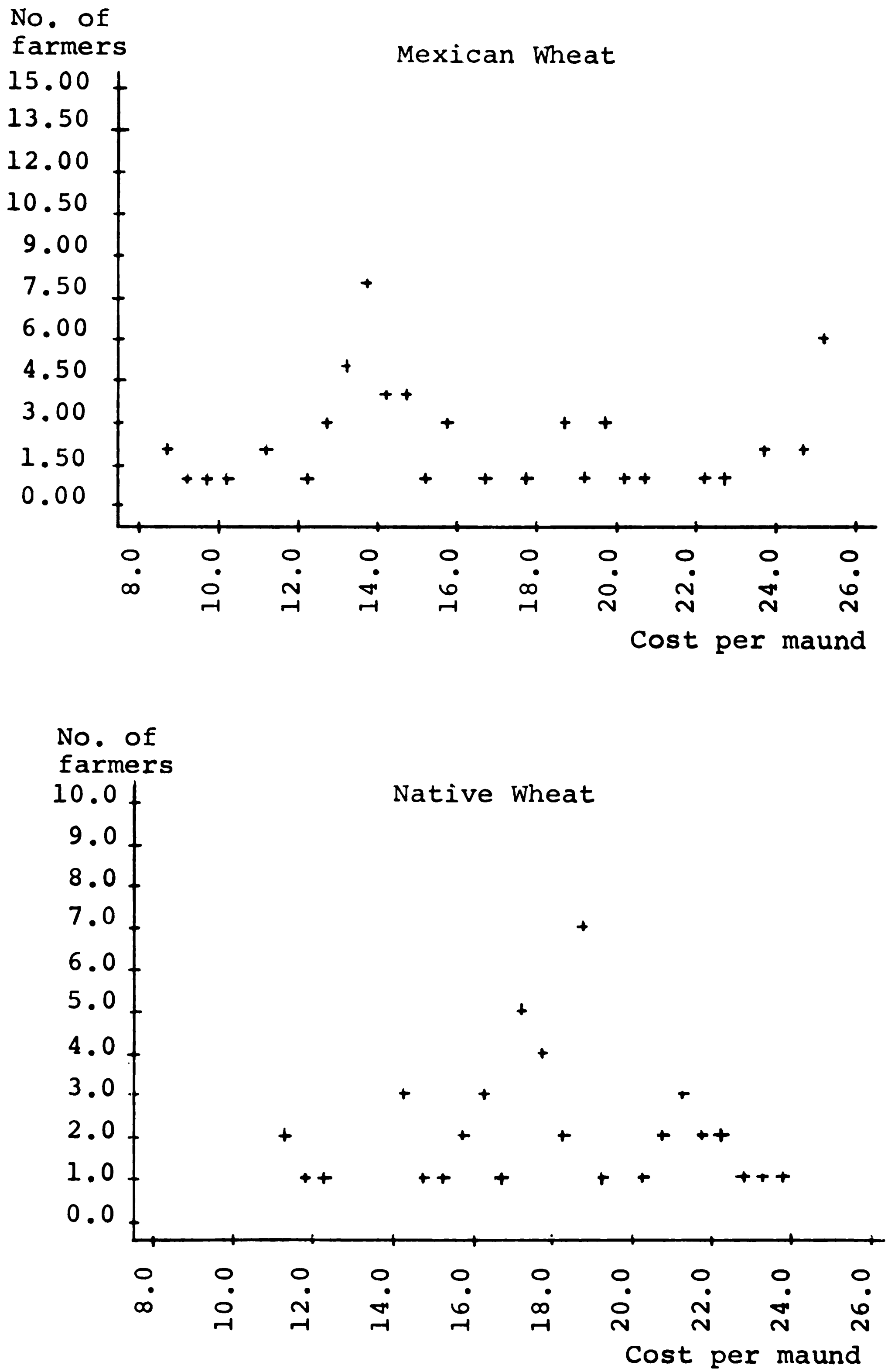
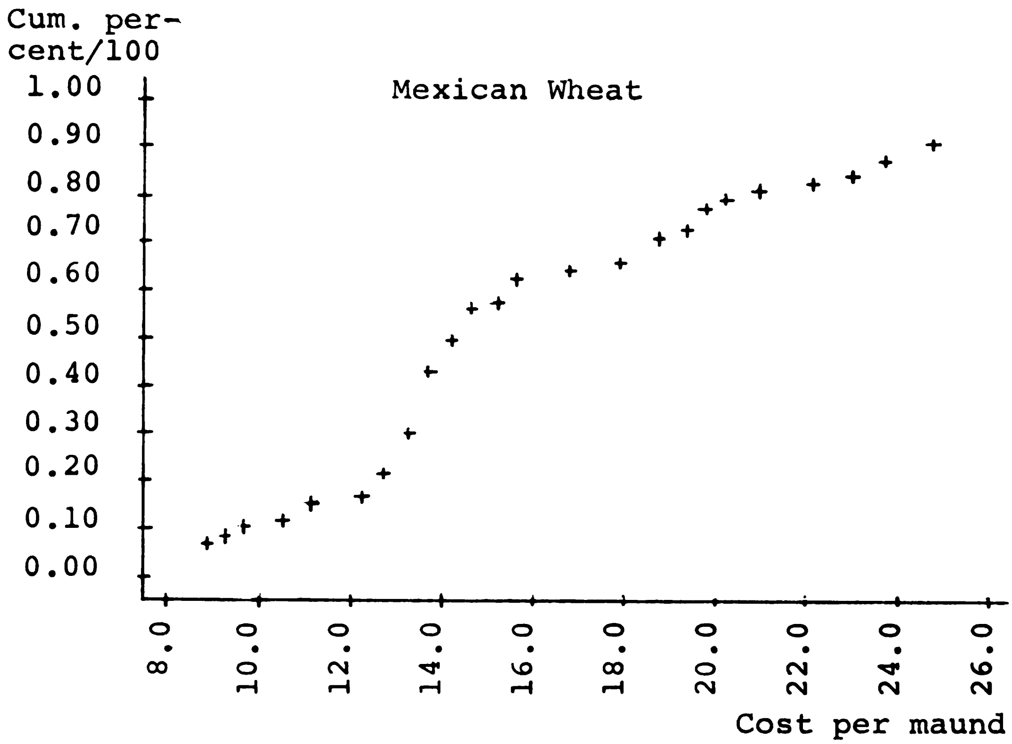


Figure 6.1--Distribution of Farmers by Cost of Production per Maund.



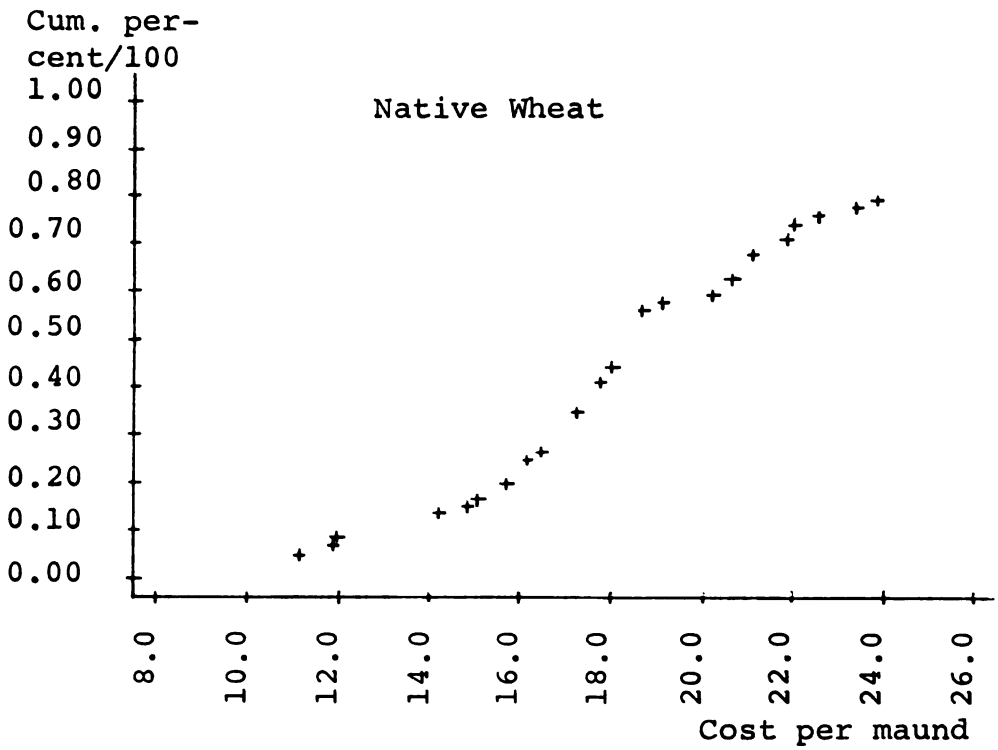


Figure 6.2--Cumulative Percent of Farmers with Production Costs per Maund between Zero and Indicated Value.

objections so long as the estimates are only compared with each other. The one point remaining is the possibility that abnormal weather might have had different effects on the two varieties. The 1968-69 season included an early spring heat wave that reduced yields through several different physiological effects on the plant.[1] Water-temperature-soil relationships were the most important of the causes of yield decline. Chapter V showed that Mexipak is far more responsive to these factors than native wheat; so in an unfavorable situation one would expect Mexipak yields to have been the more depressed. Mexipak unit costs should have been distorted upwards more than <u>desi</u> unit costs if, in fact, such a distortion took place.

Two observations are possible from Figures 6.1 and 6.2. First, the costs per maund of Mexican wheat show less central tendency than for native wheat. Current <u>desi</u> varieties have been grown widely since the late thirties or early forties. Farmers have had 30 years to select the best sets of cultural practices for <u>desi</u> wheat within the context of their own farms and prevailing price relationships. One would expect each farmer to have made gradual progress by trial and error towards an optimum allocation of his particular resources.

Mexipak is a comparatively new technology in Pakistan. The successive approximations of an optimum production environment have not run their course yet. Farmers are in the process of trying a variety of practices; some of which are suboptimal

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[1]Mexipak Wheat Yield and Quality Seed Appraisal Committee, <u>Mexipak Wheat Yield and Quality Seed Appraisal, 1969</u> (Lyallpur, September, 1969).

within their own farms. A wide range of suboptimal resource patterns would give the dispersion found in Mexipak.

The second conclusion is that to the extent there is a cluster, the Mexipak variety clusters around 14-15 rupees, while the native varieties cluster around 17-18 rupees. The lower costs for Mexipak are observed in spite of the possible upward relative bias due to weather mentioned above. Under normal weather conditions, the difference might have been more pronounced.

The explanation lies in the relationship between the differences in cost and yield. Mexican wheat, as grown in Sahiwal during the winter of 1968-69, had slightly higher costs per acre and substantially higher yields per acre. The upshot was a lower average cost per maund produced.

Thus there do appear to be differences in the variances of the distribution of unit costs and in the level of those costs. At this point in time, the dwarfs are a lower cost, but more variable cost crop. One can easily postulate situations where farmers would have to choose between uncertainty and cost.

Differences observed in the cumulative distribution curves suggest one possible use of these comparisons. One could hypothesize that only farmers who expect to cover at least their variable costs of production will grow grain for sale in the market. Quantities marketed would then be a function of the number of farmers covering their variable costs at a given price and the magnitude of the difference between cost and price. Such a relationship would make the cumulative distribution curves of Figure 6.2 a useful tool for price policy. Varying the assumed price along the horizontal axis would alter the percentage of farmers who cover costs and thus help to predict marketed quantities. The two curves could also be used to analyze the possible effects of differential price levels for native and Mexican wheats.

CHAPTER VII

SUMMARY AND IMPLICATIONS

Analyses presented in Chapter V established useful results for irrigations, nitrogen fertilization and each technique represented by a zero-one variable except line sowing. This chapter applies these results to current issues in agricultural policy.

Need for Objective Crop Estimates

Reported yields of dwarf wheat differed significantly between interviews conducted by the author and those done by his Pakistani assistant. Several pieces of evidence suggested that this was due to an under-reporting to the Pakistani to minimize the apparent contribution of dwarf wheats to the respondent's income. Even though identical questions were asked about dwarf and native wheat, significant differences in response between interviewer occurred for dwarf yields only. Farmers apparently felt no need to understate desi yields. Furthermore, several sources were cited to show that such obscurantive behavior is a long standing phenomenon on the Subcontinent.

Provincial crop estimates are prepared by aggregating reports from local officials in every small area. These men are Pakistanis and are government employees. To further complicate the matter, they are often the keeper of land records. As such, they are responsible for land tax and water rate assessment. In short, the farmer has every incentive to appear nonprosperous in the eyes of these men.

One must conclude that provincial wheat crop estimates may become quite biased downward as dwarf wheats apread over the bulk of the wheat acreage. A similar situation may also exist for the dwarf rices. It is worth noting that for the past three years, foreign specialists have consistently estimated larger crops than shown by government figures.

An objective method of estimation is vitally needed to verify the present subjective crop estimates. Without such a check, consistency in the time series data will be destroyed as dwarf wheats spread. There is presently an objective estimate of wheat production each year using a crop cutting technique. However, government seems reluctant to accept the objective estimates, preferring instead the standard system that has been used for years.

Production figures have consistently been underestimated by 20-25 per cent. Even so, the bias was uniform throughout the time series and the data could be used for some purposes. In the last two years the divergence between subjective and objective wheat estimates has increased alarmingly. Official production data today can no longer be linked to earlier years.

Two conclusions can be reached. First, objective estimates are necessary for any crop of importance especially if technological change has recently occurred. Second, government must be willing to accept the objective estimates and even to revise recent years' figures in light of them if policy is to be made intelligently.

Water Pricing and Water Management

Marginal products calculated for water were significant when water was applied to dwarf wheat, insignificant when applied to native wheat. This difference, while instructive in itself, limits the analysis that follows to dwarf wheat alone.

Water Pricing

Table 7.1 converts the marginal products estimated to marginal value products (MVP) with the assumption of a perfectly competitive product market. Two columns are shown. "MVP (expected)" values each maund at 16.00 rupees; the price farmers expected to get when they planted. "MVP (actual)" values wheat at 14.00 rupees per maund which is approximately what they received after the support price was lowered from 17.00 to 15.00 rupees just before harvest.

Irrigation water has different prices depending on the source of supply. The cost of water from the Irrigation Department canals is assessed in one lump sum. If a field is irrigated once from this source, a flat rate per acre is levied. Rates vary by crop; for wheat in Sahiwal it was 16.00 rupees per acre in 1968-69. Having once paid, the farmer then has

TABLE 7.1.--Marginal Value Product (MVP) of Water Applied to Dwarf Wheat in West Pakistan's Punjab.

Number of Irrigations	Yield	Marginal Physical Product	Marginal Value Products: Actual	Marginal Value Products: Expected
2	16.19	3.26	45.64	52.16
3	19.07	2.56	35.84	40.96
4	21.41	2.16	30.24	34.56
5	23.43	1.89	26.46	30.24
6	25.22	1.70	23.80	27.20
7	26.83	1.54	21.56	24.64
G_{xi}	27.12	1.52	21.28	24.32
8	28.31	1.43	20.02	22.88
9	29.69	1.33	18.62	21.28
10	30.98	1.25	17.50	20.00
11	32.20	1.18	16.52	18.88
12	33.35	1.12	15.68	17.92
13	34.44	1.07	14.98	17.12
14	35.49	1.02	14.28	16.32

free use of canal water for the balance of the season at a marginal cost per irrigation of zero.

In view of the calculated value of water, it is not surprising that demand far exceeds supply. Elaborate rationing systems are found in each village with the most trusted villager, often the priest, controlling a rotation schedule so that everyone receives a turn in some proportion to the amount of land farmed. This rotation will provide a varying number of irrigations to each man depending on the adequacy of the canal for the village(s) served. It was the author's observation that farmers infrequently receive as many as seven or eight canal irrigations and almost never as many as ten. Since the geometric mean exceeded seven irrigations, most farmers must turn to other sources (primarily tubewells) for supplementary water.

Insufficient data were obtained to estimate the cost to a tubewell owner of operating his well. Purchasing tubewell water from neighbors is a common practice and is taken here as the appropriate opportunity cost for owners or the actual cost to purchasers. Common practice is to sell this water by the hour of pump operation. Rates vary and the number of hours needed to irrigate an acre vary, but on the average among responding farmers an acre required 2.8 hours at 3.60 rupees per hour for a cost of Rs. 10.08 per acre-irrigation. For those who have only a Persian well for supplemental water, the cost can be taken as 15.60 rupees per acre irrigation.[1] In Sahiwal, however, this method of irrigation is becoming rare.

Of course, the calculated MVP's have greatest significance at the point of G_{x_i}. At that point an actual MVP of 21.28 rupees compares with marginal costs of zero for canal water, 10.68 rupees for tubewell water and 15.60 rupees for Persian well water. In all cases, there is a strong incentive to expand production through increased water use. In each case, physical limitations on supplies available are the effective constraints. Unless a farmer personally owns a tubewell, the first complaint made to a visitor is the inadequacy of water supplies. The present calculations suggest that this complaint often reflects the farmer's inability to apply water to the point MVP=MFC rather than his ability to irrigate enough to

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[1]To irrigate one acre with a Persian well requires four pairs of bullocks working 24 hours in three hour shifts. The approximate daily cost of a pair of bullock is 3.90 rupees.

grow a good crop. The fact that the geometric mean number of irrigations (7.19) exceeds the recommended number (5-6) is also explained by these comparisons. As long as MVP > MFC, farmers will simply expand water use until they reach the physical limits of supply. They can be expected to continue to install tubewells at a rapid rate to expand the available water quantities.

It follows that farmer investment in water development could result in more wheat than the country needs. Private and social benefits may diverge widely. There is presently no direct mechanism that would require the farmer to consider the social costs of wheat surpluses in his investment decisions.

One solution often suggested is to reduce the price of wheat, but this has proved difficult to do. After the price per maund was lowered in April, 1969 to 15 rupees, sufficient pressure was generated by agriculturally based politicians to have it again raised to 17 rupees in October.

Only at the upper end of the observed range of irrigations did marginal product fall to approximately one maund. Beyond that point, if one maund of wheat and one purchased tubewell irrigation were priced equally, farmers would cease to add irrigations. This would require a wheat price of 10.00 rupees per maund which may be too low to be politically acceptable. It should be noted that a decrease in product price would also affect the profitability of other purchased inputs notably fertilizer. If fertilization were reduced, total yields would decline. Through the reduction of $\hat{Y}$ in MPP=$b_i \frac{\hat{Y}}{X_i}$, the MVP for water would also decline and MVP=MFC would be reached at a price higher than 10.00 rupees.

Changing the relationship between water rates for different crops could conceivably divert some canal water away from wheat into other crops. But alternative water users in the winter are few at present--tobacco, sugar beets and sugar cane being the only important possibilities. The individual farmer has no way of diverting water from winter to summer seasons.

Adjusting rates for canal water leaves the profitability of tubewell irrigation untouched. In the short run, diverting canal water to other crops means that tubewell supplementation will be needed sooner and the physical limit for tubewell supplies would be reached at lower average levels. The result would be increased incentive to invest in tubewells; an incentive derived from the possibility of producing wheat in excess of the country's needs.

The question needs further research. Not all areas have exploitable ground water, and the costs of exploitation vary from place to place. But if concise analysis projects wheat production at untenable levels then the remaining alternative is to raise the price of tubewell water. Except for the small proportion of tubewells that are government-operated, this would be difficult to administer. Raising power rates would affect other uses of power. Taxing the installation process is possible but would be difficult to administer since different taxes should probably apply in different localities.

It thus seems that eventually hard decisions will be necessary with respect to the support price for wheat. Burgeoning expenses on government account must cause wheat to be re-evaluated so that private and social values are more nearly in line.

Water Management

Evidence was cited in Cahpter V from Wright that timing of irrigations with respect to the growth cycles of the plant is very important. It is particularly critical that ample moisture be available at the time of tillering and filling of the grain.

The irrigation department attempts to allocate scarce water throughout the system by a rotation where at any given time some canals are flowing at capacity, others at partial flow and a few are dry. Yet no farmer known to the author has precise knowledge of when his canal flow will be at full capacity and when it will only be a partial flow. Most of them are not certain of what dates their non-perennial canals will be turned on or off. Yet Wright shows that moisture is needed at a very precise stage in the plant's development, between the 21st and 25th days after sowing.

If farmers had accurate knowledge of their water prospects in advance, they could vary planting dates accordingly and thus gain better control of this important variable. It would seem highly advisable that the initial and final dates of flow for each water release period be announced before the season. A simple index of expected flow adequacy should also be developed and published before planting for each canal in the system. Indicating what weeks a given canal would flow, and at what strength, would help farmers plan a great deal better if the information were available early enough.

A corollary recommendation is that when the wheat in a given region is most likely to be going through the tillering and grain-filling stages, canals should be discharging at their maximum rates in that region, even at the expense of some curtailment elsewhere in the system. Following this strategy would mean reducing discharge in the Punjab early in the fall and releasing proportionately more water in the Sind where the crop is earlier. Over a period of about one month, the maximum discharge region would be shifted northward. Assuming wheat in Punjab is planted from November 1st to December 15th, maximum flows should be provided from November 20th through January 10th. Granted, there will be overlapping time periods and other problems, but this concept seems to offer a step in the direction of more efficient resource management. The management program would, however, be only partly effective unless farmers are taught the critical nature of irrigation timing.

Nitrogen Fertilization

Table 7.2 summarizes the MVP's calculated from the estimates in Table 5.7. Mexican wheat is valued at 14 rupees per maund and native wheat at 17.00 rupees. This price differential arose soon after harvest began in 1969 as a reflection of several

TABLE 7.2.--Marginal Value Products for Nitrogen Applied to Mexican and Native Wheats.

Pounds of Nitrogen	Mexican Wheat MPP	Mexican Wheat Actual MVP[a]	Mexican Wheat Expected MVP[b]	Native Wheat MPP	Native Wheat Actual MVP[c]
10	.184	2.58	2.94	.057	.97
G_{x_i} (Native)	-	-	-	.040	.68
20	.097	1.36	1.55	.029	.49
G_{x_i} (Dwarf)	.070	.98	1.12	-	-
30	.066	.92	1.06	.019	.32
40	.051	.71	.82	.015	.26
50	.041	.57	.66	.012	
60	.035	.49	.56	.010	.17
70	.030	.42	.48	.009	.15
80	.027	.38	.43	.008	.14
90	.024	.34	.38	d	d
100	.022	.31	.35		
110	.020	.28	.32		
120	.018	.25	.29		

[a]- at 14.00 rupees

[b]- at 16.00 rupees

[c]- at 17.00 rupees

[d]- Native wheats seldom receive more than 80 pounds of nitrogen.

factors of both supply and demand. An expected MVP column is included for dwarf wheat as in the section above based on 16.00 rupees per maund. The reduction in support price generally affected only dwarf wheat. Native wheat prices remained above floor price levels in the 1969 and 1970 harvests.

The government attempts to standardize the price of a pound of nitrogen at .50 rupees (50 paisa) regardless of source. During the winter of 1968-69, critical shortages developed and a black market in fertilizer flourished. Most sales were concluded at 23 per cent[1] above the official price or 61.5 paisa per pound of nitrogen. In addition, some small cost is involved in transportation between retail outlet and the farm. Under these conditions, a pound of nitrogen may be assumed to have cost the farmer between 60 and 65 paisa in 1968-69.

One conclusion then is that Punjabi farmers almost exactly equated marginal value product and marginal factor cost when fertilizing native wheats. Chemical fertilizer and the present desi varieties have both been available since 1953. Repeated trials have evidently given farmers a precise definition of their high profit point in combining the two.

A corollary conclusion is that fertilizer applications to native wheat should be directly responsive to changes in the price of either product or input.

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[1]Thirty-two rupees per bag of Urea compared to the official rate of 26.

The geometric mean of nitrogen applied to dwarf wheat was in excess of 28 pounds. At this point, the actual marginal value product was 98 paisa. Farmers are presently in a transition phase, experimenting with dwarf wheats and heavier fertilizer use will expand considerably before an equilibrium is reached. The black market has disappeared and nitrogen is now selling at slightly less than the controlled rate. The total cost to the farmer including transportation is between 50 and 55 paisa. If the wheat price support is maintained at 17.00 rupees per maund, nitrogen use will expand until the geometric mean dose is between 60 and 70 pounds. Even if the procurement price is reduced to 15.00 rupees, more than 50 pounds will be applied.

As long as MVP > MFC, usage will expand if possible. A reduction in product price or an increase in factor price will not automatically result in using less of the factor.

However, a potential surplus problem is again evident. Acreage of Mexican wheats exceeds 7.0 million irrigated acres in 1969-70 and is expected to increase still further. If the sample represents these irrigated acres well, then the geometric mean of nitrogen applications will eventually approach 60 pounds. Estimated yields at this level exceed one ton per acre so this acreage alone will contribute over 7,000,000 tons of product. An additional 8,000,000 acres are grown with yields of one-third of a ton. Total production could exceed 9.5-10.0 million tons. Such a production increase could seriously strain government's capacity to buy and store wheat if it occurred rapidly. In addition, huge amounts of rupees would be needed to procure the wheat that would be offered to government.

A related problem is the 25 per cent subsidy on fertilizer. Each pound of nitrogen costs the government 17 paisa on the average. If 60 pounds are made available for each of 7,000,000 acres, 71,000,000 rupees will be required for fertilizer subsidies alone. Such resources will probably not be made available. Either fertilizer use must be curtailed or the subsidy eliminated, or a combination of both.

These calculations indicate that the subsidy could be entirely removed without constraining nitrogen use below 50 pounds of nutrient per acre. Were the subsidy to be removed immediately, fertilization of dwarf wheat would continue to expand until they reached this level. At the same time, there would be some reduction in fertilization of desi wheat.

A matrix of expected fertilization levels can be developed for various prices of nitrogen and wheat. Table 7.3 presents such a matrix. The figures within the cells are geometric means of optimum fertilization levels rounded to the nearest ten-pound unit.

Summary

Insights were obtained about several variations in wheat growing techniques. Line sowing was not found to produce significant results. Date of planting variations did contribute to explaining variation in yields. In the case of dwarf wheat,

TABLE 7.3.--Expected Fertilization Rates Under Different Prices of Wheat and Nitrogen.

Price of Wheat (Rs./Md.)	Nitrogen Price (paisa/pound)						
	40	45	50	55	60	65	70
13.00	70	60	50	50	40	40	40
15.00	80	70	60	60	50	50	40
17.00	90	80	70	70	60	50	50

the data confirmed the planting date recommendations of the government.

Significant differences were found in the reporting of yields to the two interviewers which seemed to reflect a downward bias when farmers respond to a Pakistani from outside their village. As a result, objective estimation methods were strongly urged for all crops which are the subject of major provincial policies.

Water applied to dwarf wheats was found to be very profitable at present levels. Physical limitations of water supply seem to be the effective constraint to further irrigations. Profit motives seem strong enough in light of the data herein to induce rapid development of additional water supplies, primarily from tubewells. It is possible that private efforts to maximize profits through tubewell construction could lead to wheat surpluses that would burden the nation. Alternative price adjustments to forestall such an event were explored.

The data showed that the expansion of nitrogen fertilization of dwarf wheats is far from complete. Again, adjustment to the high profit point (MVP = MFC) could result in unnecessary surpluses of grain. Price adjustments for wheat and fertilizer were explored that would allow equating MVP and MFC at various fertilizer doses.

Finally, the probable effects of removing the subsidy on fertilizer were briefly discussed. This discussion can also be carried forward with slight modification to estimate the effects of currency devaluation on the quantity demanded of imported fertilizer.

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APPENDICES

APPENDIX A

LIST OF INDIGENOUS TERMS AND MEASURES

Units of Measure

1. Weight

   Maund = standard unit of measure for agricultural produce = 82.28 pounds

   Seer = 1/40 of a maund = 2.057 pounds

   Chhattank = 1/16 of a seer = 2.057 ounces

2. Area

   Square = 27.5 acres. One of the basic units in which land was allocated during settlement of the canal colonies.

   Rectangle = 25 acres. One of the basic units in which land was allocated during settlement of the canal colonies. Often called a square in popular usage.

Urdu Terminology

bajra - pearl millet

barani - land which has only natural precipitation as a source of moisture. A barani farmer is one who farms under these conditions.

bund - elevated earthen ridge separating fields, usually with a footpath on top.

chapati - flat bread which is the dietary staple in West Pakistan. It is prepared by grinding whole wheat, kneading with water, pressing into a pancake shape and frying on a dry griddle.

gur - raw native sugar boiled down from sugarcane juice.

jowar - sorghum.

kammi - a village artisan, usually landless, who supplies his services year 'round in return for payment in kind at harvest. Examples are cobbler, barber, carpenter, blacksmith, priest and watchman.

kera - sowing method where seed is dropped by hand directly into the furrow as it is plowed. Effects line sowing but little control of seed depth.

kharif - summer growing season. Roughly from mid-May to mid-November

loessi - summer beverage made from home-made yogurt, water and salt and chilled if ice is available.

nambardar - village headman, usually a hereditary position. Responsible for representing the village in all contacts with the government and for some taxation and assessment within the village.

persian well - large diameter, hand-dug well rarely exceeding 30 feet in depth. Water is elevated by a continuous chain of buckets or pots which empty as they pass over a drive wheel. Powered by animals.

pora - sowing method where seed is dribbled by hand into a funnel on the back of a native plow and falls through a tube into the furrow as it is plowed. Some control of seed depth is obtained.

rabi - winter growing season. Roughly from mid-November to mid-May.

tehsildar - administrative officer responsible for record keeping, taxation and routine administration of the lower level administrative unit known as a tehsil.

tubewell - a small diameter borehole (2-6 inches) lined with sieves which may exceed 200-300 feet in depth and is powered by an electric or diesel engine.

APPENDIX B

THE QUESTIONNAIRE

Interviewer: ______________________ Interviewer's Remarks
Date: ______________________
Tehsil: ______________________

IDENTIFICATION

1. Farmer's Complete Name: ______________________

2. Village Name or Chak Number (Print): ______________________

FARM CHARACTERISTICS

3. How many acres do you cultivate? __________

4. How much is owned ________ rented __________

5. How much of your wheat crop does the zamindar get? ______%

   How much do you get? __________%

6. Does the zamindar help pay for:

a.	Seeds	Yes	____	No	____	How much?	____%
b.	Fertilizer	Yes	____	No	____	How much?	____%
c.	Water	Yes	____	No	____	How much?	____%
d.	Land Revenue	Yes	____	No	____	How much?	____%
e.	Others ______________________					How much?	____%

7. How many acres of wheat are you growing?

a.	This year (1968/69)	Dwarf	____	Desi	____	Total	____
b.	Last year (1967/68)	Dwarf	____	Desi	____	Total	____
c.	2 years ago (1966/67)	Dwarf	____	Desi	____	Total	____
d.	3 years ago (1965/66)	Dwarf	____	Desi	____	Total	____

8. What other crops are you growing this rabi season?

Crop	Acreage	Other Crops (specify)	Acreage
Berseem	______	______________	______
Sugarcane	______	______________	______

NOTE: If the sum of #7A plus #8 does not equal #3, find out why and enter other land uses here.

DWARF WHEAT — Go to one of his fields of dwarf wheat. Draw a map on back of previous page that identifies the field's location.

9. What variety is planted here?

   Mexipak White ____ Mexipak Red ____ Sonora ____

   Lerma Rojo ____ Penjamo ____

10. How big is this field _____ acres _____ kanals?

11. What day did you plant this field? (circle one)

   October: 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

   November: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

12. In preparing this field, did you use:

   Bullocks ____ (Go to #16) Tractor ____ (Go to #13)

13. If #13 is Tractor, then:

   a. What kind of tractor? ____________ Don't know _____

   b. What model number? _______________ Don't know _____

   c. How many Horse Power? ____________ Don't know _____

   NOTE: If tractor is nearby, look at it after interview to verify a and b.

14. How many hours did the tractor actually work in this field?

   Plowing ________________ Hours

   How many plowings ____________

   Other jobs ____ Hours
   (specify which ones)

   Total _______________ Hours

15. If tractor was hired, how much was paid to prepare this field? _____________

16. If #12 is Bullocks, then:

   How many bullocks were used in preparing this field? ______

   NOTE: If answer given is an odd number, find out why.

17. How many days/hours did each team of bullocks spend in this field on the following:

	Team 1	Team 2	Team 3	
Plowing	______	______	______	Days or Hours
Sohaga	______	______	______	Days or Hours
Karah	______	______	______	Days or Hours
Other (specify)	______	______	______	Days or Hours
Other (specify)	______	______	______	Days or Hours
Total	______	______	______	Days or Hours

NOTE: If given in DAYS, then how many hours do the bullocks work each day? ________

18. How much is each bullock worth? If you sold them today, how much would you get for them? ________

19. How much do you feed each pair of bullocks each day?

Seers of Bhoosa ______________

Seers of berseem or green cut corn ___________

Seers of other (specify) _____________

20. How many hours/days did you work on this field yourself before planting? ___________

Doing what jobs? ___________

21. What other people also worked on this field before planting?

Relative (R) Villager (V) Outsider (O) (circle one)	Job Performed (fill in)	Hours or Days spent on this field (fill in)
a. R V O	______________________	______ hr/da
b. R V O	______________________	______ hr/da
c. R V O	______________________	______ hr/da
d. R V O	______________________	______ hr/da
e. R V O	______________________	______ hr/da

22. How many seers of seed did you use on this field? _______
How was seeding done? Broadcast _____ Rabi Drill _______
Tractor-drawn Drill ________

23. Where did you get the seed?

a. Bought from ADC ________________ Price Md. _______

b. Bought from shopkeeper ___________ Price Md. _______

c. Obtained from neighbor ___________ Price Md. _______

d. Produced yourself last year _______

24. How much fertilizer did you put on this field before planting?

Kind	# of bags on whole field	Weight of each bag	Price per bag
__________	__________	________	__________
__________	__________	________	__________

25. How many total maunds of wheat did you grow last year?

Dwarf: _______ maunds produced _______ maunds per acre

Desi: _______ maunds produced _______ maunds total

26. How many maunds did you sell: Dwarf: ____ maunds sold

Desi: ____ maunds sold

27. How many maunds were paid to others:

To whom	Maunds given	To whom	Maunds given
__________	__________	__________	__________
__________	__________	__________	__________
__________	__________	__________	__________

28. Did you have a crop planted on this field during the following seasons:

a. Kharif 1968 What crop ____________________

b. Rabi 1967/68 What crop ____________________

c. Kharif 1967 What crop ____________________

29. Will you plant a crop on this field during next Kharif:

Yes ________ No _______

If yes, what crop? ____________________

DESI WHEAT Go to one of his desi fields. Draw map on back of opposite page that identifies the field's location.

30. How big is this field? _________ acres _______ kanals

31. What day did you plant this field? (circle one)

<u>October</u>: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
18 19 20 21 22 23 24 25 26 27 28 29 30 31

<u>November</u>: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
18 19 20 21 22 23 24 25 26 27 28 29 30 31

32. In preparing this field, did you use:

Bullocks ___ (Go to #35) Tractor ___ (Go to #33)

33. If #32 is Tractor, then:

How many hours did the tractor actually work in this field?

Plowing _________ Hours How many plowings? ___________

Other jobs ____________________________ Hours
(specify)

Total ______________________ Hours

Who drove the tractor? ____________________________________

34. If tractor was hired, how much was paid to prepare this field? _______________

35. If #32 is Bullocks, then:

How many bullocks were used in preparing this field? _______

NOTE: If answer given is an odd number, find out why.

36. How many days/hours did each team of bullocks spend in this field on the following:

	Team 1	Team 2	Team 3	
Plowing	______	______	______	Days or Hours
Sohaga	______	______	______	Days or Hours
Karah	______	______	______	Days or Hours
Other (specify)	______	______	______	Days or Hours
Other (specify)	______	______	______	Days or Hours
Total	______	______	______	Days or Hours

37. How many hours/days did you work on this field yourself before planting? _____________

Doing what jobs? ___________

38. What other people also worked on this field before planting?

Relative (R) Villager (V) Outsider (O) (circle one)	Job Performed (fill in)	Hours or Days spent on this field (fill in)
a. R V O	____________	______ hr/da
b. R V O	____________	______ hr/da
c. R V O	____________	______ hr/da
d. R V O	____________	______ hr/da
e. R V O	____________	______ hr/da

39. How many seers of seed did you use on this field? ________

How was seeding done? Broadcast _____ Rabi Drill ________
Tractor-drawn Drill ________

40. Where did you get the seed?

a. Bought from ADC ____________ Price Md. ________

b. Bought from shopkeeper ____________ Price Md. ________

c. Obtained from neighbor ____________ Price Md. ________

d. Produced yourself last year ________

41. How much fertilizer did you put on this field before planting?

Kind	# of bags on whole field	Weight of each bag	Price per bag
________	________	________	________
________	________	________	________

42. Did you have a crop planted on this field during the following seasons:

a. Kharif 1968 What crop ____________________

b. Ravi 1967/68 What crop ____________________

c. Kharif 1967 What crop ____________________

43. Will you plant a crop on this field during next Kharif?

Yes _______ No _______

If yes, what crop? ________

Condition of Field:
Color ________
Stand ________
Other ________

Date ________

Farmer's Name ________

Village Name/Chak No. ________ Tehsil ________

DWARF WHEAT (Return to the same dwarf field you saw before.)

44. What source of water was used for this field?
Canal _____ Tubewell _____ Persian Wheel _____ Rainfall Only

45. How many times did you irrigate? (circle one)
1 2 3 4 5 6

46. Did you irrigate before planting? Yes ____ No ____

47. How much do you pay for water? Rs. _____ Per _____

48. Who does the work of watering? ________

49. How long does it take to water this field? ________ Hrs.

50. Did your wheat receive any rain? Yes ____ No ____
How many times did it rain? ________
Light Rain _____ Good Rain _____ Heavy Rain _____

51. Did you have any problems getting water?

____

____

____

____

52. How much fertilizer did you put on this field?

Kind	Price Per Bag - Rs.	No. of Bags On This Field	When Applied

53. How was the fertilizer applied? By whom? ________

Broadcast _______ Pora _______ Drill _________

54. a) Where did you buy your fertilizer?

____

(Town) (Type of Distributor)

b) How far away is this? _____________ Miles

55. Did you have any problems getting fertilizer? Yes ___ No ___

If Yes, what kind of problems?

____

____

____

____

56. Did you pay cash or buy on credit? Cash ___ Credit ___

57. How much fertilizer did you put on dwarf wheat?

a) Last Year (1967/68) _____ bags/acre, No Dwarf Wheat ____

b) Year before (1966/67)____ bags/acre, No Dwarf Wheat ____

58. When do you expect to begin harvesting this field? (circle one)

March 20 21 22 23 24 25 26 27 28 29 30 31

April 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

May 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

P.T.O.

Condition of Field:
Color ______
Stand ______
Other ______

Date ______

Farmer's Name ______

Village Name/Chak no. ______ Tehsil ______

DESI WHEAT (Return to the same desi field you saw before.)

59. What source of water was used for this field?
Canal ___ Tubewheel ___ Persian Wheel ___ Rainfall Only ___

60. How many times did you irrigate? (circle one)
1 2 3 4 5 6

61. Did you irrigate before planting? Yes ____ No ____

62. How much do you pay for water? Rs. ______ Per ______

63. Who does the work of watering? ______

64. How long does it take to water this field? ______ Hrs.

65. Did your wheat receive any rain? Yes ____ No ____
How many times did it rain? ______
Light Rain ____ Good Rain ____ Heavy Rain ____

66. Did you have any problems getting water?

______

______

______

______

67. How much fertilizer did you put on this field?

Kind	Price Per Bag - Rs.	No. of Bags on This Field	When Applied

68. How was the fertilizer applied? By Whom? ________

Broadcast _____ Pora _____ Drill _____

69. a) Where did you buy your fertilizer?

____
(Town) (Type of Distributor)

b) How far away is this? ________ Miles

70. Did you have any problems getting fertilizer? Yes ___ No ___
If yes, what kind of problems?

____

____

____

71. Did you pay cash or buy on credit? Cash ____ Credit ____

72. How much fertilizer did you put on desi wheat?

a) Last year (1967/68) ______ bags/acre, No Desi Wheat ____

b) Year before (1966/67) ______ bags/acre, No Desi Wheat ____

73. When do you expect to begin harvesting this field?
(circle one)

March 20 21 22 23 24 25 26 27 28 29 30 31

April 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26 27 28 29 30

May 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Name ______________________________ Chak ____________________

NOTE: Emphasize that you want to talk just about the two fields that were selected for study.

His Dwarf field was ____ acres _____ kanals

His Desi field was _____ acres _____ kanals

HARVESTING

74. How many people helped cut your field of dwarf wheat? _______

75. How long did it take them to get that field cut? ______ hrs.

76. How many people helped cut your field of desi wheat? _______

77. How long did it take them to get that field cut? _______ hrs.

78. How much did you pay each of them? _________ per acre/day

THRESHING

79. Did you thresh your wheat with? Bullocks ____ or Machine ____

80. Did you thresh each of the two fields separately?

Desi: Yes ____ No _____ Dwarf: Yes ____ No _____

(If bullocks)

81. How many pairs of bullocks did you use? __________

82. How many people helped with threshing? ___________

83. How long did it take to thresh your dwarf field? ______hrs.

If not threshed separately, how many hours to thresh 1 acre of dwarf wheat? ___________

84. Did you pay these people? Yes ___ No ___ Cash ___ or Wheat ___

85. How much did you pay them? _______ per day/maund

86. How long did it take to thresh your desi field? __________hrs.

If not threshed separately, how many hours to thresh 1 acre of desi wheat? _________

87. Did you have any difficulty getting enough people to cut and thresh your wheat? Yes ____ No ____

If yes, what kind of difficulty?

88. (If machine), What kind of machine? ________________
How many hours to thresh 1 acre? ______
If rented, how much did it cost? ______

WINNOWING

89. How many people helped winnor your wheat? __________

90. How long did it take to winnor your dwarf field? ______hrs.
If not done separately, how long to winnow 1 acre of dwarf? __________

91. How long did it take to winnow your desi field? ______ hrs.
If not done separately, how long to winnow 1 acre of desi? __________

92. How much were these people paid? ________ (per maund)

OTHER

93. Did any one help move the grain to your home? Yes __ No __

94. What is the price of Bhoosa in your village?
In June: Rs. ___ per maund In March: Rs. ___ per maund

95. What is the price for renting farm land around this village?
Rs. _______ per acre/year

YIELDS (These are the most important questions)

On the Dwarf field we have been studying:

96. How many acres or kanals were harvested? ______________

97. How many total maunds did you get from this field? _______
that means _______ mds/acre (CALCULATE AND CHECK)

On the Desi farm we have been studying:

98. How many acres or kanals were harvested? _________

99. How many total maunds did you get from this field? __________
That means ________ mds./acre (CALCULATE AND CHECK)

MISCELLANEOUS

Last year the Government price was 17 Rupees:

100. What did you sell your desi wheat for? _____Rs.
Did not sell _______

101. What did you sell your Mexi wheat for? ____ Rs.
Did not sell _____

This year the Government price is 15 Rupees: Have you sold any wheat yet?

Yes _____________ No _______________

What price did you get for? Will you sell some later?

102. Desi ____ Rs. Mexi ____ Rs. Yes ______ No _ ______

103. What price will you expect to get for?

Desi ____ Rs. Mexi _____Rs.

104. Where will you sell your wheat?

Govt. Procurement Center ______ Neighbors in the Village _____
Arhti ______ Beopari ____ Other _______

105. Why don't you sell directly to the Government for 15 rupees?

If the Government reduces the official price to 10-12 rupees/maund next year:

106. How much wheat will you plant? ________ (acres)

107. What kind of wheat will you plant? Mexi 591 273 H-68
Dirk etc.

Why?

108. Will you use more or less fertilizer? More ____ Less ____

How much more or less? _________

109. Will you use more or less water? More _____ Less ______

Why?

When we were here last you said you had irrigated your two fields as follows:

Mexipak: ______ irrigations Desi: ______ irrigations

110. Did you put any more water on after our last visit?

Yes _______ No _______

If yes, how many extra irrigations: Mexipak ____ Desi ____

111. Is fertilizer still sold on Black Market since Martial Law?

Yes _______ No __________

APPENDIX C

GEOMETRIC MEANS OF INPUT LEVELS APPLIED BY SAMPLE FARMERS TO MEXICAN AND DWARF WHEATS (on per acre basis)

	Mexican Wheat	Native Wheat
Bullock-Pair-Hours	36.412	33.475
Seers of Seed	35.000	34.078
Number of Irrigations	7.189	6.166
Pounds of Nitrogen	28.371	14.496
Pounds of Phosphate	1.328	1.107
Farm Yard Manure[1]	2.204	2.925
Yields	19.708	15.363

[1]In units of 5 maunds or 411 pounds.