Wheat in the Cotton-Based Cropping Systems of the Irrigated Sindh

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PARC/CIMMYT Paper 90-4

Agricultural Economics Research Unit (PARC),
Agriculture Research Institute, Tandojam
Sindh Agriculture University, Tandojam
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Preface

In 1986, the Pakistan Agricultural Research Council, Islamabad, established an Agricultural Economics Research Unit, (AERU) at Agricultural Research Institute, Tandojam, with the follwing objectives:

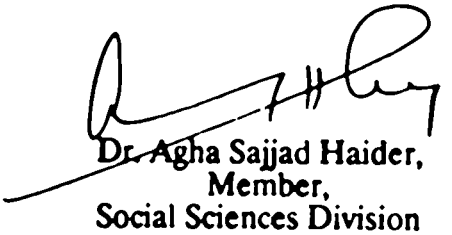
- To conduct farm level research in collaboration with biological scientists and social scientists of Agricultural Research Institute, Tandojam to understand specific farming systems, diagnose factors limiting productivity and evaluate technological alternatives for overcoming these problems.

- To feed back information from this research to help establish priorities for research on experiment stations

"Wheat in the Cotton-based Farming Systems in the Irrigated Sindh", is one of the series of studies being conducted by the Unit in close collaboration with agronomists and economists at ARI, and Sind Agriculture University, Tandojam. This study is based on extensive farm level surveys and crop cuts by a multi-disciplinary team. The data were anslysed in detail to address special problems of planting wheat after cotton in central Sindh.

In addition to describing priorities for future research and extension work in the cotton-wheat areas, it also provides a valuable set of data on cropping patterns, wheat production practices, yield and profitability. It also identifies the factors limiting wheat productivity in the context of the cotton-wheat farming system of the central Sindh. It is hoped that it will prove useful for researchers, extension workers and policy makers and also provide a sound basis for carrying out similar work on cropping systems in different agro-ecological zones of Pakistan.

I appreciate the efforts of the research staff in bringing out this publication.



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Abbreviations

AERU:	Agricultural Economics Research Unit
ARI:	Agriculture Research Institute
SAU:	Sind Agriculture University
PARC:	Pakistan Agricultural Research Council
CIMMYT:	International Maize and Wheat Improvement Centre

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Executive Summary

- The cotton-wheat cropping system is the most important in Pakistani agriculture. In Sindh more than one million hectares of wheat is cultivated, out of which almost 80% of area is grown under the cotton-wheat cropping systems. However, current research and extension recommendations do not differentiate between wheat sown after cotton and wheat sown in other rotations.

- A diagnostic survey of wheat was conducted in the cotton-wheat area of Sindh during the 1988-89 crop cycle. The major objectives of this survey were to identify factors affecting wheat productivity and to plan an on-farm experimentation/extension programme. A formal survey of wheat production practices and yields at harvest time in 100 randomly selected fields was undertaken. Production practices were recorded in the short interview with farmers in their fields and yields were measured by harvesting and threshing three to five plots of dimension $1m^2$ located randomly in the fields.

- Wheat after cotton was the major crop rotation in the area. About 45% of wheat fields were planted after cotton, and 24% after fallow.

- Late harvesting of cotton is the major time conflict in the rotation, resulting in late planting of wheat. Wheat after cotton was planted on an average 20 days later than wheat after other kharif crops or fallow. About 60% of wheat following cotton was planted after November 15th, resulting in low potential yields.

- The majority of the farmers prefer the cotton variety Niab-78 in the cotton-wheat rotation. The variety is early in maturity and harvesting can be completed two weeks earlier than with other recommended variety.

- The farmers generally weigh up the benefits of an additional cotton picking with the loss from later wheat planting. The results shows that even taking into account high picking costs for the late picking, the benefits of extra picking are likely to outweigh the loss in wheat yields due to its late planting.

- The majority of farmers (34%) planted the wheat variety Pavon. This variety was used for both early and late planting. In addition, 48% of farmers used non-recommended varieties, i.e. Yecora, Mexi-Pak, Pak-70 and WL-711. The problem of slow uptake of new varieties reflects an inadequate distribution system for certified seed as well as farmers lack of awareness of the danger of a rust epidemic from using banned varieties.

- Chemical fertilizer was used by 98% of the sampled farmers. Most farmers are aware of the need to apply both nitrogenous and phosphatic fertilizers, although the fertilizer applications are well below the recommended rates. A quarter of the farmers applied 75% or more of the recommended level of nitrogen. Only 3% of the sampled farmers used phosphorus at the near the recommended dose.

- Ten weed species were found infesting the wheat crop. The Singh (Honey clover) had the highest intensity of occurrence (25%) followed by Dumbi Grass (Phalaris minor) with 22% infestation. Farmers with no weed problem in their field got high yield of 3572 kg/ha as compared to 2175 kg/ha who faced serious weed problem in their wheat fields.

- Irrigation is provided by perennial canal and supplemented by tubewells. The number of irrigations given to wheat varied from 3 to 8, with an average of 5 irrigations.

- Delayed harvesting well beyond maturity was a common practice, especially among large farmers who depend on hired labour for harvesting. The harvest index averaged 33% but declined by over 3% from early harvested fields to late harvested fields. These late fields were also late planted and hence subject to more heat stress during flowering and grain formation.

- The average measured wheat yields from the 100 samples was 3024 kg/ha. One third of fields yielded less than 2000 kg/ha and only 17% yielded above 4000 kg/ha. The characteristics of the high yielding fields were: a) wheat after fallow; b) better land preparation, c) planted before November 15th; d) more irrigations and; e) application of more chemical fertilizer. Conversely, low yielding fields had usually been planted after cotton, with banned and mixed varieties and with more weeds present and more salinity problem in the fields. Multiple regression analysis of yields confirmed most of these factors as significantly affecting yields.

- Farmers paid over one quarter of their wheat production or 10.8 kg per 40 kg for harvesting, threshing and marketing costs. Farmers received a net price of Rs 78 per 40 kg and the net value of the wheat standing in the field was Rs 57 per 40 kg yield after subtracting harvesting, threshing and transport costs.

- The net returns of low yielding fields (< 2000 kg/ha) and high yielding fields (> 3500 kg/ha) were calculated and showed a wide difference. The net return of low yielding fields covered only variable costs but did not give a reasonable return on capital to farmers. The net return in high yielding fields was enough to give a reasonable return on capital to farmers. This shows the importance of cost reducing technologies if wheat is to remain competitive.

- Major problems exist with late planting of wheat, broadleaf weeds, salinity, use of banned and mixed varieties, irrigation, water efficiency and land management efficiency. An on-farm experimental research program is suggested to overcome some of these problems.

WHEAT IN THE COTTON-BASED FARMING SYSTEMS OF THE IRRIGATED SINDH

Introduction

Wheat is the major food crop of Pakistan and grown on an area of 7.30 million hectares with a total production of 12-15 million tons, with an average yield of just under 2 t/ha (Government of Pakistan, 1987). In Sindh, the mean yield of cotton-wheat areas is 2.2 t/ha, almost double that of the rice-wheat areas (1.3 t/ha). Nevertheless, the present wheat yield per hectare is far below the production potential of recommended wheat varieties. This is attributed to many factors, out of which management practices, input use and weed control are of primary importance.

The cotton-wheat crop rotation is the most important one in Sindh. Of more than one million hectares of wheat, 78% is in the cotton-wheat area (Table 1). The remaining 22% of area is grown in areas predominated by rice-wheat and rice-sugarcane cropping systems.

The purpose of this study is to describe and analyse the special problems of planting wheat after cotton in Sindh. This report is concerned with the first part of an on-farm research process, that is the diagnostic survey. The specific objectives of the study are:

- To provide a general overview of wheat production practices, cropping patterns and crop rotations in which wheat is produced in cotton-based cropping systems of Sindh.

- To diagnose major agronomic and socio-economic constraints limiting productivity in cotton-wheat areas with specific reference to wheat.

- To delineate homogeneous group of farmers or recommendation domains for organizing research priorities and recommendations for wheat.

- To identify the factors related to policy and policy implementation which constrain farmers adoption of improved technology.

Table 1. District-wise Area and Production of Wheat in the Major Cropping Systems in Sindh, Mean Values 1984-85/1985-86

Districts	Wheat			
	Irrigated		Non-Irrigated	
	Area (000 ha)	Yield (t/ha)	Area (000 ha)	Yield (t/ha)
Cotton-Wheat System				
Khairpur	99	2.21	5	1.50
Sukkur	107	2.03	12	1.11
Nawabshah	187	2.52	3	1.38
Sanghar	153	2.33	-	-
Tharparkar	130	2.24	-	-
Hyderabad	101	2.28	-	-
Rice-Wheat System				
Jacobabad	41	1.16	5	0.82
Shikarpur	25	1.31	-	-
Larkana	47	1.56	6	-
Dadu	62	1.53	9	0.88
Rice-Sugarcane System				
Badin	32	1.02	-	-
Thatta	5	1.24	-	-
Sindh Province:	**990**	**1.78**	**40**	**1.09**

Source: Agricultural Statistics of Pakistan 1986, Mean Value 1984-85/1985-86

Methodology

This study involved gathering both primary and secondary data to describe wheat production practices and related issues in the study area.

Collection and Compilation of Secondary Data

Secondary data were collected on different variables like temperature, rainfall, area, yield and production of wheat. Data sources were: Development Statistics of Sindh, Agricultural Statistics of Pakistan and data obtained from the Statistics Department, Agriculture Research Institute Tandojam and Agriculture Extension, Hyderabad.

Population and Sample

Irrigated cropping of wheat and cotton in rotation is concentrated in Khairpur, Sukkur, Nawabshah, Sanghar, Tharparkar and Hyderabad districts of Sindh (Figure 1). For this study, four districts were randomly selected i.e. Hyderabad, Sanghar, Nawabshah and Khairpur respectively. The major survey areas are shown in Figure 2. These four districts jointly contribute 60% of the total wheat cultivated area in Sindh. Thirty two villages were randomly selected from eight talukas of four districts (Table 2). The probability of selection of the sample village in each taluka was proportional to the area under wheat crop for the village. From each village, an average of three to four farmers was chosen randomly. One hundred farmers were selected randomly from the four districts.

Questionnaire Development

A questionnaire was developed and pretested before conducting the formal survey. The questionnaire included general questions regarding crops, input costs, crop rotation and physical productivity.

One section of the questionnaire contained information relating to the socio-economic characteristics of the respondents. These variables include tenure, farm size, marketing infrastructure, labour and credit availability.

The last section of the questionnaire contained questions on crop production practices, i.e. land preparation, planting method, input use, number of irrigations, etc. (Appendix I), relating to the specific field of wheat where the "crop cut" (estimation of yield by cutting samples) was undertaken.

Field testing of the questionnaire enabled the researcher to improve upon the overall organization of the layout, clarity and suitability of the questions. Modifications made were based upon the field test.

Data Gathering Techniques

Surveyed farmers were interviewed personally at wheat harvest time (April 1st to 15th, 1989). The farmers were interviewed on their farms. Before the interview, the researchers explained the purpose of the research and assured the respondents that all information was confidential. Approximately fifty minutes to one hour was required to conduct each interview.

Fig. 1. Cotton Wheat Area in Sindh

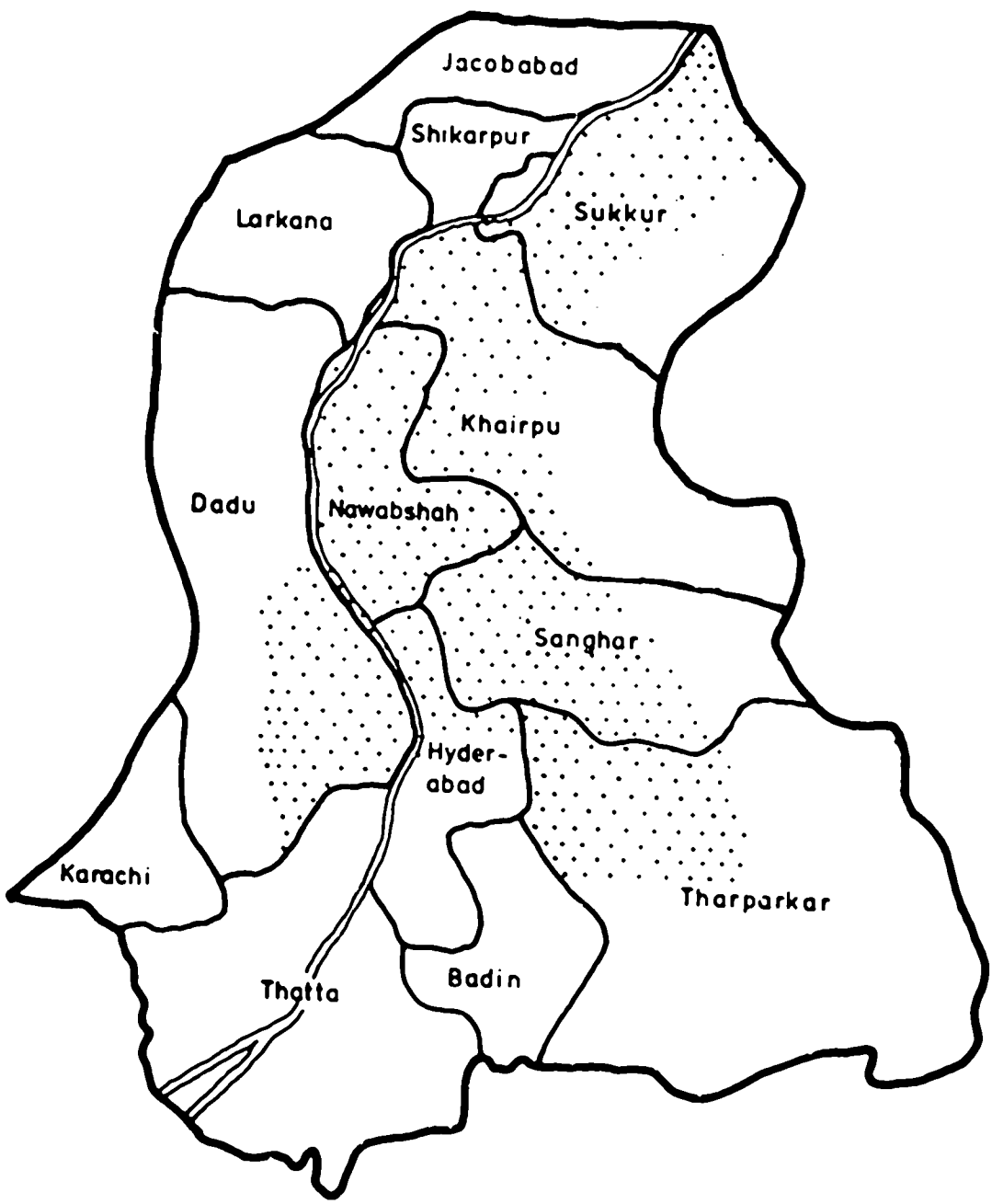


Fig. 2. Map Showing Survey Area of Sindh 1989

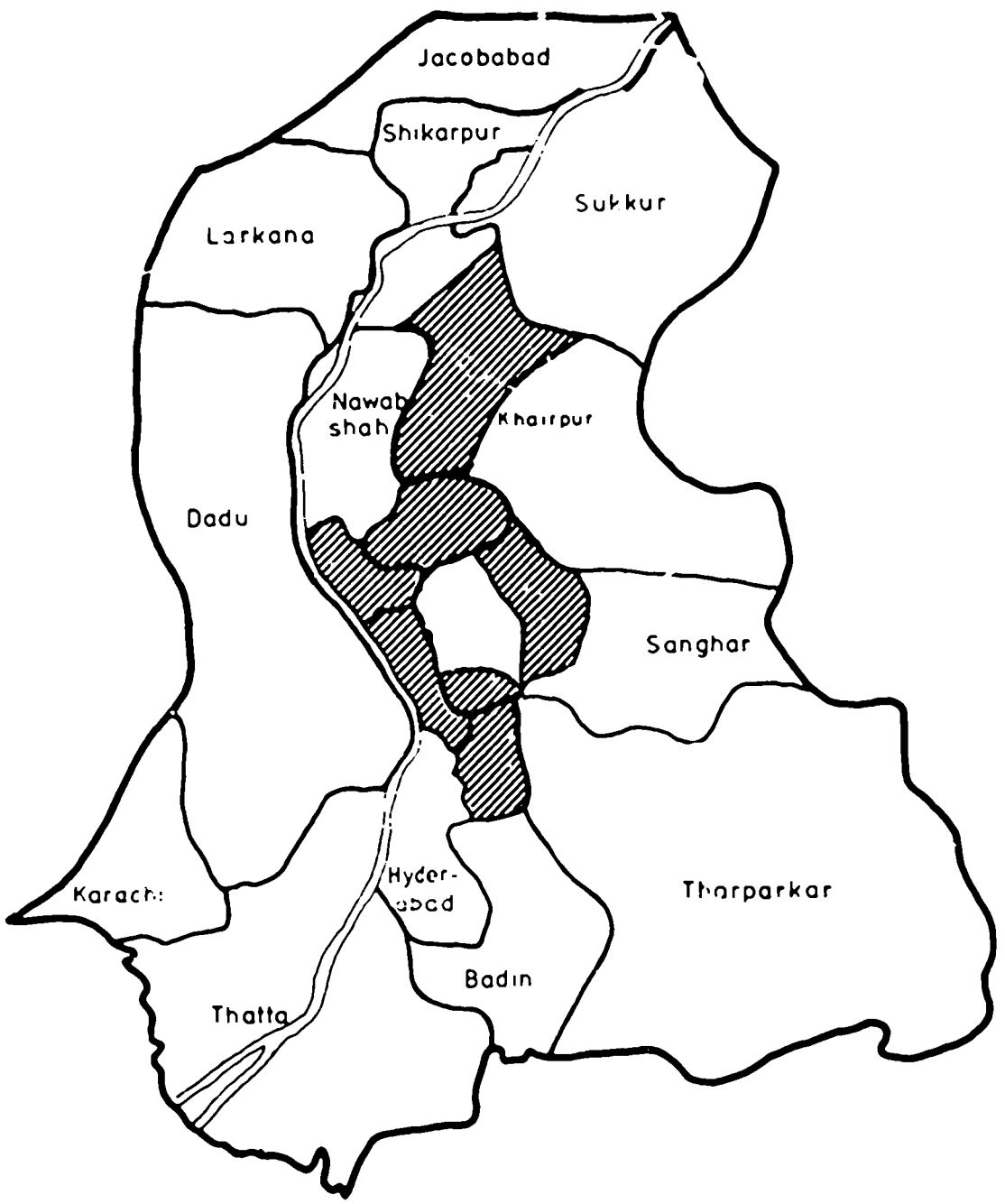


Table 2. Distribution of Sample Villages and Respondents in the Study Area

District/Taluka	Village	Percentage
Hyderabad		
Tando Allahyar	4	13
Hala	4	12
Sanghar		
Tando Adam	5	15
Sanghar	3	10
Nawabshah		
Sakrand	4	13
Nawabshah	4	12
Khairpur		
Faiz Gung	5	15
Kotdiji	3	10
All	32	100

In addition to the interview, a number of observations were made in the sampled fields. Weeds were counted in each sampled fields within 3 sq. meter with the help of weed scientists (Plant Physiology Section, A.R.I.) Tandojam. Also soil salinity problems were scored using the following scale:

0 = No problem
1 = Some problem
2 = More problem
3 = Serious problem

At the same time, three to five plots (depending upon the variability in the field) of dimension $1m^2$ were located randomly in the field and samples were harvested, weighed and threshed to estimate yields following methods described in Catling, Hobbs, Islam and Alam (1983). Two to three kilograms of wheat seed of a new variety was given to each sampled farmers free of cost, in order to compensate for wheat grain-taken by the researchers, and to gain the farmers confidence.

Data Analysis

The "Statistical Package for Social Sciences, (SPSS)" was used for analyzing the data. The conceptual framework guiding the analysis is shown in Figure 3. The first round of the data analysis focussed on the farmers natural and socio-economic environment, and the cropping system. The second part described the inter-relationship between specific wheat production practices (such as between variety and date of planting) and between the cropping system and production practices in wheat (e.g. between previous crop and date of planting). Finally, we diagnosed the major factors limiting productivity and drew implications for research and extension.

The Cropping System

Land Use and Cropping Patterns

Wheat and cotton are the major crops in the sampled areas, accounting for 52% and 75% of cropped areas in the rabi and kharif cycles during 1985-86, respectively (Table 3). Area and yield of cotton and wheat in the studied areas have been almost stagnant from 1981-82 to 1987-88 (Figures 4 & 5). The areas of maize, other kharif fodder and rabi fodder are sizeable, due to the importance of fodder markets for livestock in Hyderabad and Karachi. The specific crop rotations in the surveyed area are shown in Table 4. In the sampled areas, 45% of wheat was grown after cotton, 24% after fallow, 10% after sugarcane, 3% after bajra, 5% after rice and 6% after jowar. Therefore cotton-wheat rotation was the dominant one and of the special interest to this study.

Cotton-Wheat System

Where wheat is grown in rotation with cotton, time conflict between the crops can arise. A major problem for wheat in the cotton-wheat rotation is delayed picking of cotton, with the resulting late planting of wheat (Akhtar, et al. 1986). For cotton generally planting is not constrained by wheat harvest dates. The recommended planting period for wheat in the studied areas is from first week of November to first week of December. This allows and reduces the risk of exposure to hot weather in the critical period of flowering and grain formation. The major factors influencing cotton harvesting and hence the late planting of wheat include: (1) the planting time of cotton; (2) variety of cotton;(3) yield of cotton; and (4) turnaround time from cotton to wheat.

Figure 3. Conceptual Framework for the Analysis of Wheat in the Cotton-Based System

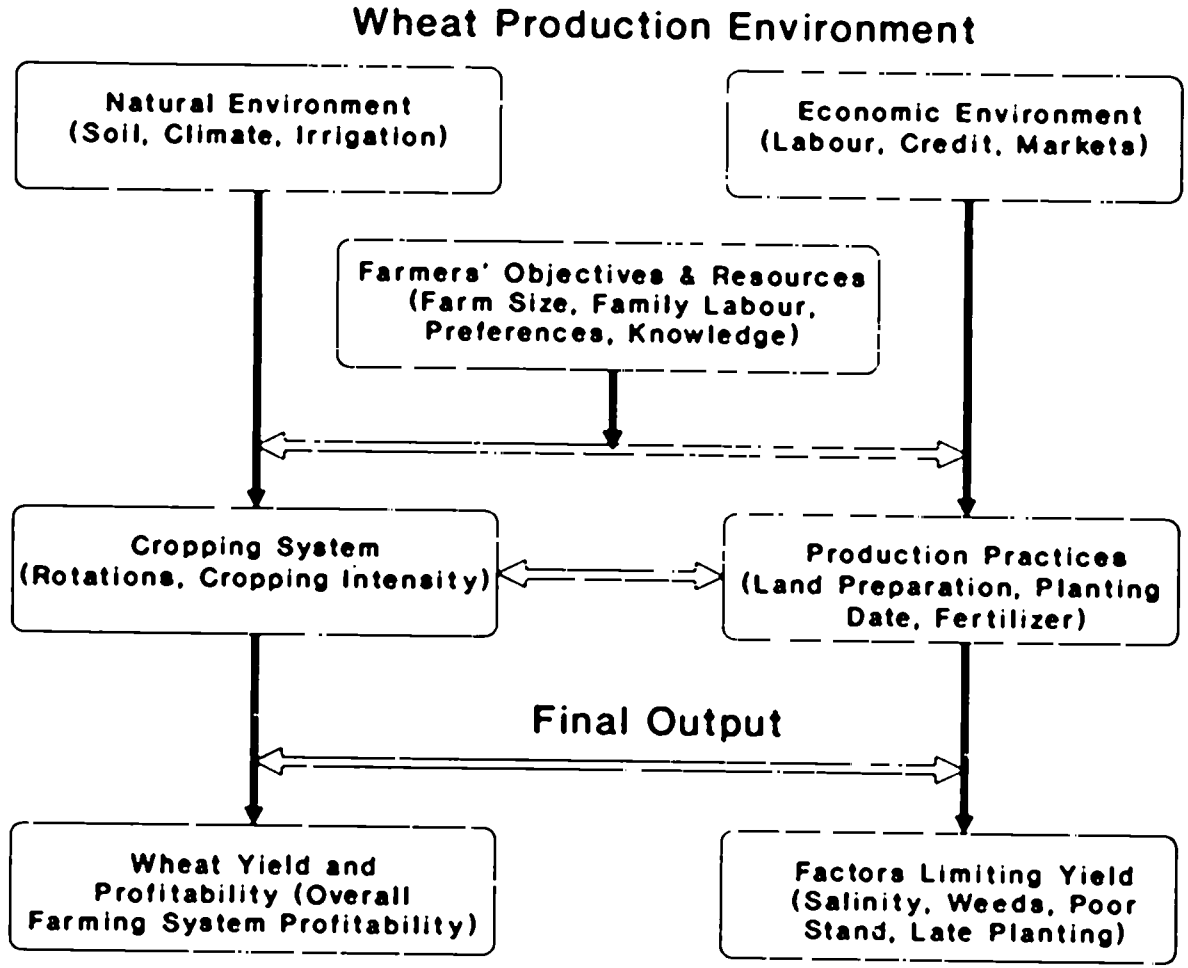


Figure 4
Wheat and Cotton Area, 1982-88 in Cotton-Wheat Areas of Sindh

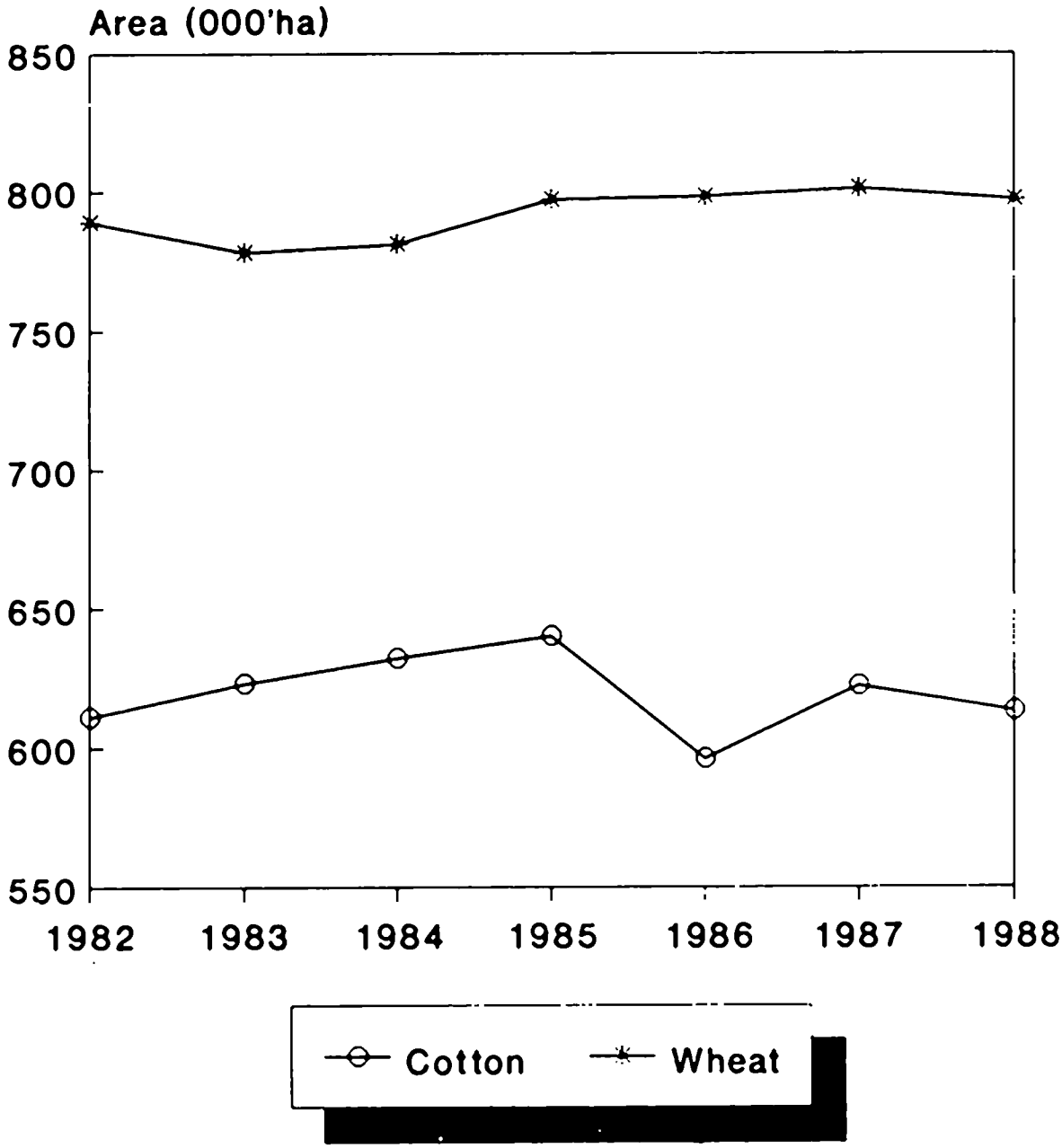


Figure 5
Wheat and Cotton Yield 1982-88 in Cotton-Wheat Areas of Sindh

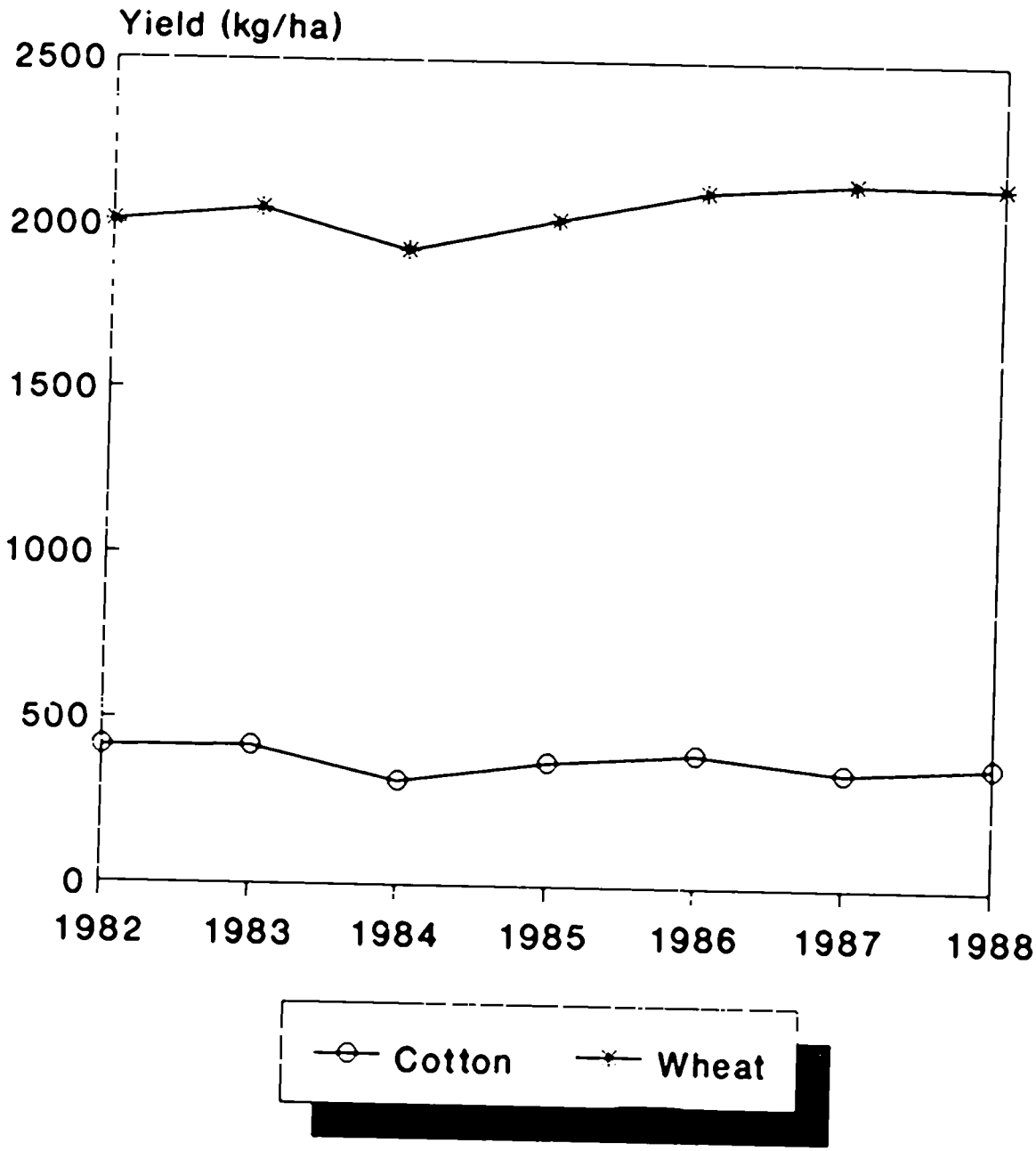


Table 3. Area Under Different Crops in Rabi and Kharif Seasons in Cotton-Wheat Areas of Sindh, during 1985-86

Crops	Area * (000 ha)	Percent
Kharif Crops		
Cotton	99	52
Sugarcane	19	10
Rice	8	4
Maize	3	6
Bajra	44	20
Jowar	8	4
Other crops (Pulses, vegetables)	20	4
Total Kharif	**189**	**100**
Rabi Crops		
Wheat	133	75
Barley	2	1
Rapeseed/mustard	15	8
Guar seed	8	5
Other crops (Pulses, vegetables)	20	11
Total Rabi	**178**	**100**

* Excluded area under fodder and garden.

Table 4. Frequency of Crop Rotation in Cotton-Wheat Areas, 1988-89

Cropping Pattern in 1988-89	Percent of Wheat Fields
Cotton-Wheat	45
Fallow-Wheat	24
Sugarcane-Wheat	10
Vegetable-Wheat	7
Bajra-Wheat	3
Rice-Wheat	5
Jowar-Wheat	6
All	**100**

Planting Date of Cotton

Cotton planting commenced in the first week of April and continued until the second week of June in the studied areas. However, most planting occurred during mid April to mid May. There was little evidence of early cotton planting, leading to earlier wheat planting, although late planted cotton did tend to result in wheat planted in December. Early planting of cotton is also not recommended; a significant reduction in yields has been recorded in date of planting experiments, because early cotton tends to mature in the monsoon period.

Cotton Variety

When cotton follows wheat, 75% and 25% of farmers planted NIAB-78 in Sanghar and Khairpur districts respectively (Khushk et al. 1988). This variety is early maturing and picking can be completed about two weeks earlier than the other recommended varieties (Akhtar et al. 1986). Even so, NIAB-78 provides lower quality so fibre it fetches a lower price in the market. However, farmers prefer this variety in the cotton-wheat rotation. MNH-93 gives a higher quality staple and is mostly planted by larger farmers.

Yield of Cotton

Late planting of cotton, significantly affects the yield. Higher yields of cotton were significantly related to number of cotton picks. Cotton pickings ranged from two to five, with an average of three (Khushk et al. 1988). Each additional picking added about 15 days to the cotton production cycle. Farmers usually weigh up the benefits of an additional cotton picking with the costs in term of late wheat planting (Akhtar et al. 1986). Farmers estimated that the last pick increased yield on average by about 200 kg/ha. At mid 1980s prices 200 kg of cotton was approximately equal in value to 600 kg of wheat to the farmers, as calculated by Akhtar et al. 1986. The benefits of the additional pick were estimated to outweigh the loss in wheat yield due to late planting.

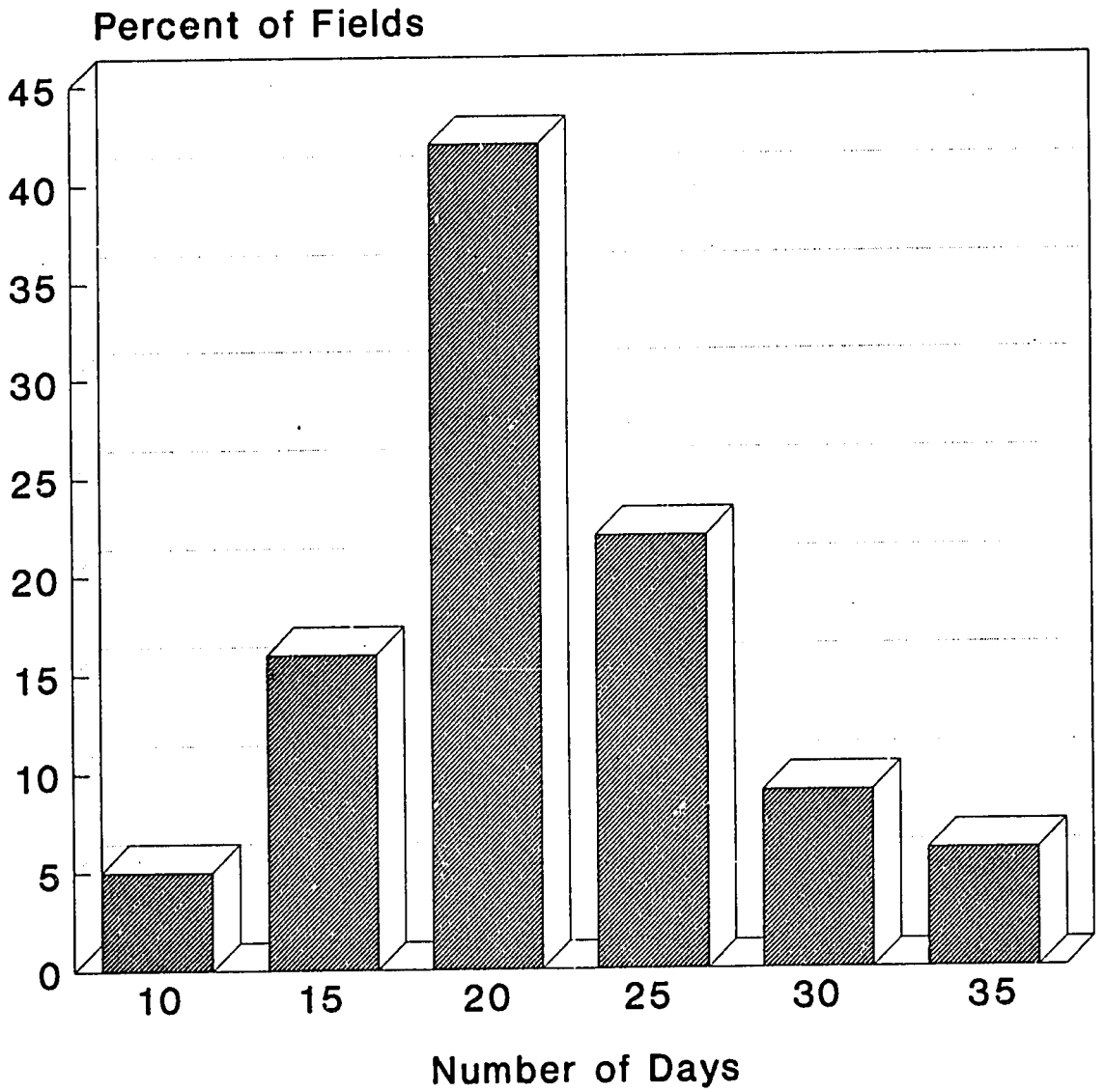
Turnaround Time from Cotton to Wheat

The average turnaround time from the last picking of cotton to the planting of wheat is about 20 days. This period is required to clear cotton residues and prepare the land for the next crop. Farmers sometimes have to wait for water and appropriate moisture conditions of the field before planting of wheat. Figure 6 shows little variation in the turnaround time from cotton to wheat and these differences do not seem to be important in explaining differences in planting dates for wheat. Zero tillage of wheat after cotton has been tested recently in Sindh, and is a promising technology.

Fallow

In rabi cycle of 1987-88, an average 30% of farm area was left fallow. Likewise about 24% of wheat fields were planted after fallow in the previous kharif cycle. These figures indicate the importance of fallow in the rotations. The major

Figure 6
Frequency Distribution of Turnaround Time from Cotton to Wheat, 1989



reasons for leaving land fallow are; a) shortage of water and b) conflicts in the cotton-wheat system. At the same time there is a highly significant positive relationship between the percentage area in fallow and farm size. Large farmers generally prefer the cotton-fallow-cotton rotation because: a) wheat is often uneconomic when planted late after cotton and b) cotton yields more after fallow because of better land preparation and higher fertility.

Other Rabi Crops: Wheat Versus Fodder and Oilseed

Rabi fodder (Berseem) is the major competitor to wheat for land in this area. However, the proportion varies among different categories of farmers. Only a few farmers had no berseem, reflecting water shortage and land scarcity. The rotation of wheat with berseem is an important management practices to control weeds and maintain fertility levels, especially by small farmers. The berseem is mostly planted near the villages.

Rapeseed/mustard are also planted by small farmers. These crops were sown on about 55,000 ha. in the cotton-wheat areas of Sindh. The yield of rapeseed/mustard in Sindh is very low compared to the potential yield. The major reasons for low yield are: a) majority of the growers planting in saline (kalar) soil and in poor land, those lands are not useful for wheat or other crops and b) management practices, growers generally do not plant in time, low use of fertilizer and no weed control practices.

Wheat Production Practices

Land Preparation

Land preparation for wheat is generally performed by tractor and or draught animals and then followed by planking. About 40% of sampled farmers prepared their land with draught animals. Another 18% of the farmers used tractors only and the remaining 42% used both tractors and animals for land preparation. The number of ploughings varied from two to eight with an average of four. Tractor rental charges were Rs 150 to 175 per hectare for ploughing and Rs 60 per hectare for planking. On average, the total cost of ploughing and planking to be paid by farmers was Rs 500 to 1375 per hectare for land preparation.

The cropping pattern partly determines the number of tillage operations. In the case of wheat after cotton, only four ploughing were done. This is mainly due to little time left for tillage. For wheat after fodder or fallow, an average of five ploughings was done with land preparation started in September.

About half of the land was prepared under "Wat Khair" condition (residual moisture). Farmers irrigate for the following wheat crop when cotton is still in the field. After the last picking of cotton and the removal of sticks, the residues of the cotton crop must also the removed or incorporated to obtain a good seed bed for wheat. Mostly farmers manually remove cotton sticks from the field and store them for use in their home for fuel.

Planting Method and Seed Rate

The most common method of wheat planting was broadcasting. Only one farmer used a drill for planting wheat. Two different methods of broadcasting seed were observed in the area. Two thirds of the farmers used the "Ghurbi" method. With this, farmers prepare their land by ploughing and planking. They then irrigate their fields and broadcast the wheat seed into the stagnant-water. This method of wheat planting is generally used with clay or heavy soils. This method needs care from birds until the seed germinates. One third of the farmers used the "Wat Khair" method. With this, farmers first irrigate their fields followed by ploughing at the right moisture. The wheat seed is broadcast and incorporated by one ploughing and one planking. This method is commonly used in those fields where soil is light or sandy.

The seed rate ranged from 100 to 200 kg/ha with an average of 135 kg/ha. Farmers, who planted late, used about 5 kg/ha more seed than those who planted earlier in order to compensate for lower wheat tillering.

Variety

During the survey seven wheat varieties were recorded in the sampled areas. "Pavon" was the most common and was planted by 34% of the farmers. This variety was used for both early and late planting. In addition, 48% of farmers used other non-recommended varieties such as Yecora, Mexipak, Pak-70 and WL-711. Sonalika/Blue Silver was grown by 16% of the farmers. This is an old variety and is still recommended for late planting despite its susceptibility to rust. Other new recommended variety TJ-83 were used by only 2 percent of farmers (Table 5).

The problem of slow uptake of new varieties in Sindh is serious. The Sindh-81, TJ-83 and Sarsabz were released in 1981, 1983 and 1985 respectively, but still they have not been widely adopted by the farmers. The question arises whether the farmers are unfamiliar with these new varieties or whether they know about them but do not want to adopt them. Further research is needed on this issue.

Non-recommended, banned and mixed varieties are susceptible to the rusts and loose smut. If farmers are not aware of this, there is a need to assess yield losses from the use of mixed seed and non-recommended varieties. The results should then be disseminated among the farmers. Furthermore, some of new released varieties show some signs of rust susceptibility (PARC, 1987). There is a need to assess the actual rust risk in the Sindh, as well as yield losses resulting from the use of present varieties.

Table 5. Wheat Varieties Planted in Cotton-Wheat Areas in Sindh, 1989

Varieties	Percent Area Planted
Recommended	
TJ-83	2
Pavon	34
Blue Silver	16
Sub-Total:	52
Non-Recommended	
Yecora	20
Mexipak	8
Pak-70	5
WL-711	15
Sub-Total:	48
Total	100

Planting Period

The recommended planting period in the sampled areas ranges from November 1st to November 30th. Most farmers (92%) planted wheat during the recommended time (Table 6). The results further shows that lowest yields were received those who planted after December 1st and highest yield were received those who planted during the second and third week of November.

Table 6. Planting Period and Wheat Yield in Cotton-Wheat Areas in Sindh, 1989

Planting Period	Percent Fields	Yield kg/ha
November 1st week	45	2989
November 2nd week	30	3205
November 3rd week	15	3203
November 4th week	2	2998
December 1st week	3	2832
December 2nd week	5	1999
All	100	3074

Fertilizer

Fertilizer application is essential to obtain optimum yield of wheat. Table 7 shows the recommended fertilizer application to wheat by the Agricultural Department and the farmers actual application of fertilizer to their fields. 85 kg/ha of phosphorus and 138 kg/ha of nitrogen are recommended overall for the wheat crop. The common dose of fertilizer was one bag/acre of DAP at sowing time and one bag/acre of urea with the first or second irrigation. The farmers were aware of the importance of both nitrogen and phosphatic fertilizer.

Table 7. Average Dose of Nitrogen and Phosphorus in Relation to Recommendation in Cotton-Wheat Areas, 1989

Fertilizer	Average Dose Fertilizer Applied Kg/ha	Recommended Dose Kg/ha*
Phosphorus	45	85
Nitrogen		
Basal Application	30	69
Top Dress	72	69
Total Nutrients	147	223

*Recommendation of Wheat Program, Agriculture Research Institute, Tandojam, 1988-89

The fertilizer application rates are well below the recommended rates Twenty five percent of the farmers applied 75% or more of the recommended level of nitrogen. Only 3% of the farmers used phosphorus at or near the recommended dose (Table 8). However, the recommended phosphorus level is far too high to be economical to farmers.

Table 8. Classification of Farmers According to the Level of Nitrogen and Phosphorus Applied to Wheat in Relation to Recommended Dose, Cotton-Wheat Areas, 1989

	Nitrogen	Phosphorus
	Percent of all farmers	
Percent applied nutrients	98	80
Applied less than 25% of recommended dose.	4	21
Applied 25% to 75% of recommended dose	71	76
Applied over 75% recommended dose	25	3
Total:	100	100

Weeds and Weed Problem

Ten weed species were found infesting the wheat crop and are given in Table 9 in order of their occurrence. Among the weeds recorded, Singh (Honey Clover) had the highest intensity of occurrence i.e. 25%, followed by the Dumbi Grass (Phalaris minor) with 22% infestation. These two are the most common weeds of wheat. Other weeds identified were: Jhil (Lambs quarters) 12%, Javi (Wild oat) 8%, Naro (field bind weed) 6%, Basari (Wild onion) 6%, Neli (Scarlet pimparmal) 4%, Kabah (Nut Sedge) 6%, Chabbar (Bermuda grass) 6% and Palak (Wild spinach) 5%.

Table 9. Weeds and their Infestation Percentage in Wheat Fields, During 1988-89

Local Name	English Name	Percent Area Infested
Singh	Honey clover	25
Dumbi grass	Phalaris minor	22
Jhil	Lambs quarters	12
Javi	Wild oat	8
Naro	Field bind weed	6
Basari	Wild onion	6
Neli	Scarlet Pimpermal	4
Kabah	Nut Sedge	6
Chabbar	Bermuda grass	6
Palak (Wild)	Wild Spinach	5
All		**100**

Incidence of Weeds

Data shown in Table 10 reflect the incidence of weed problem. In the sample, 14% of farmers stated no weed problem in their wheat field, compared to 24% who reported a serious problem. Almost half of the farmers reported many or serious weed problems. There was a strong relationship between the incidence of weeds and wheat yields (Table 10). For example, farmers with no weed problem in their field averaged 3572 kg/ha as compared to 2175 kg/ha for those who identified serious weed problems in their field.

Table 10. Farmer's Assessment of Incidence of Weeds and Grain Yield by Weeds

Incidence of Weeds	Percent Farmers	Yield Kg/ha
No Weeds	14	3572
Some Weeds	39	3327
Many Weeds	23	2794
Weeds Serious	24	2175
All	**100**	**3024**

Reasons for Weed Free Fields

Those farmers who did not face a weeds problem in their wheat field were further asked the reasons for the absence of weeds in their wheat field. More than half the growers responded that they had good land preparation before the wheat sowing. 22% had fallow land in Kharif season, 12% had rotated with berseem after two-three years and 10 % stated that they have grown wheat somewhat earlier (Table 11).

Table 11. Farmers Assessment About Weed Free Wheat Fields, During 1989

Reasons	Percent
Better Land Preparation	56
Previous Fallow	22
Crop Rotation	12
Early Sowing	10
All	100

Weed Control Methods

Most farmers were following traditional weed control methods. These methods were varying from farmer to farmer according to their knowledge, type of land, land holding, and socio-economic and agro-ecological conditions. The following methods were identified in the sampled farmers (Table 12).

- Hand weeding, used by the majority of the farmers (74%). Mostly small farmers used family labour for weed control and they feed the pulled weeds for their animals. Hand weeding of Phalaris is difficult due to its high density and its resemblance to wheat in its early growth stage.

- Use of chemicals to control weeds have become popular recently, because of their effectiveness and the higher labour cost for manual weeding. As well, herbicides offer farmers the option of more timely planting by reducing cultivations between the kharif and rabi crops (Zulfiqar et al. 1988). The use of herbicides shows positive effect on the grain yield of wheat. Some farmers (9%) had applied weedicide in their wheat field, but most of the sampled farmers used hand weeding in their field.

Table 12. Effect of Different Weed Control Methods on Grain Yield of Wheat Crop, 1988-89

Weed Control Method	Percent Farmers	Average Wheat Yield Kg/ha	Prob.
Hand Weeding	74	2710	.06
Weedicide Use	9	3600	
No Weed Control	17	2473	
All	**100**	**2928**	

Reasons for Non-Adoption of Herbicides

Farmers in the studied area were generally aware of the benefit of herbicides. However, the adoption rate was very low. Data for non-adoption of herbicides are shown in (Table 13). The majority of the growers (52%) replied that weed control by herbicides is too expensive, 30% did not apply because they used weeds as fodder, 10% and 8% of farmers did not use herbicide due to financial constraints and share cropping, respectively.

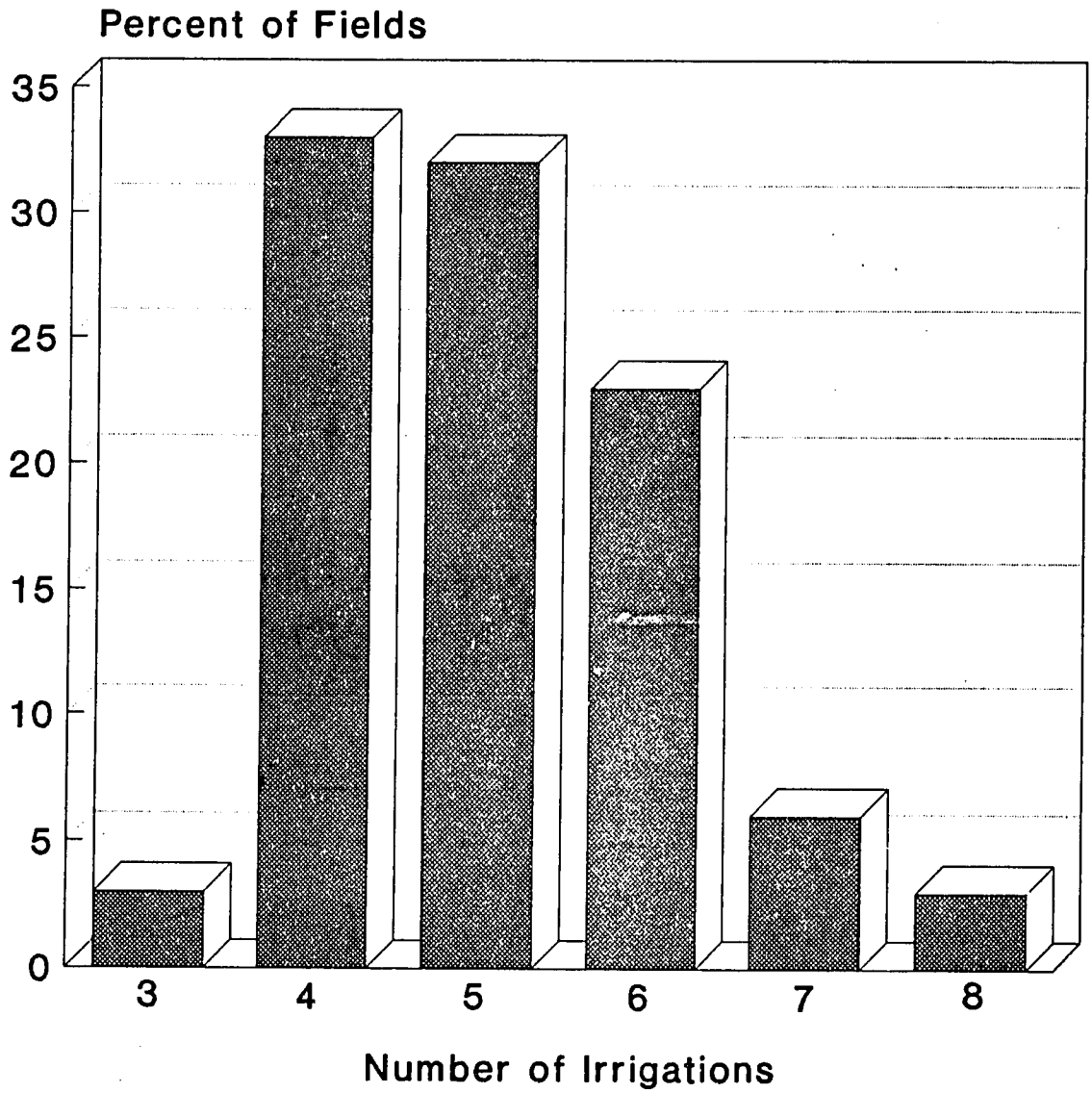
Table 13. Perceptions of Farmers for Non-Adoption of Herbicides in Wheat Fields, 1988-89

Reasons	Percent
Too Expensive	52
Used for Fodder	30
Financial Constraints	10
Share Cropping	8
All	**100**

Irrigation Scheduling

The total number of irrigation given to wheat varied from three to eight with an average of five irrigations (Figure 7). The number of irrigation depended on farmers access to irrigation, water and rainfall during the crop cycle.

Figure 7
Number of Irrigations to Wheat in Cotton-Wheat Areas, 1989



In wheat following cotton, farmers normally planted on "Wat Khair" condition due to lack of time after cotton picking. However, after fallow, kharif fodder, vegetables and other crops, always used "pre-irrigated method" prior to planting. This method is important to incorporate and decompose crop residues and also to control weed. Fields planted "Wat Khair" received one less irrigation than pre-irrigated fields.

Figure 8 shows the relationship between yield and the number of irrigations, but the relationship is not statistically significant. The response of wheat to irrigation scheduling depends on many factors such as rainfall, timing of irrigation, soil type and quantity of water given per irrigation.

Harvesting, Threshing and Disposal

Wheat is harvested manually starting from April 1st and continues up to the second week of May, with a peak harvesting period from April 10 to April 30. Harvesting of wheat was done by family and hired labour. The majority of the growers (56%) used their family labour and remaining 44% used family as well as hired labour. Harvesting charges varied from 150 to 300 kg/ha (about 10% of crop) depending on the crop condition in a particular field. Harvesting is done by both male and female labour. Four to five male labourers can harvest one acre in one day.

It was noticed that many farmers delayed harvesting well beyond maturity. This practice was most widespread among large farmers who depend on hired labour for harvesting. The lower Sindh i.e. Hyderabad, Tharparkar, and Sanghar generally escapes from the severe wind and rain storms that damage mature wheat fields in upper Sindh. However, there is some evidence that there was a loss in grain due to shattering in late harvesting fields.

The harvest index averaged 33%, and declined by 3% from early harvesting fields to late harvested fields. This partly reflects the fact that late harvested fields were also late planted and hence subject to more heat stress but we believe that losses due to shattering were also important. Further research on this issue is needed, in order to establish priorities for mechanization of harvesting and for breeding of varieties resistant to shattering.

Threshing of wheat was done by tractor operated mechanical threshers. Threshing charges varied from 5 to 7 kg/md with an average of 5 kg/md or farmers pay 10 to 12 rupees per mds. Ninety nine percent of sampled farmers used threshers for wheat threshings. Usually labour for threshing was provided by the farmers but if it is provided by the owner of the thresher, the charges increase by one kg/mds. Mostly farmers use exchange labour for threshing. In addition to harvesting and threshing farmers also pay for marketing and transportation services. These costs are listed in Table 14. Effectively, farmers paid an average of 10.8 kg per 40 kg (27%) of the production for harvesting, threshing and marketing. Farmers received a net price of Rs 78.20 per 40 kg and the net value of the wheat standing in the field was Rs 57.0 per 40 kg of yield after subtracting harvesting, threshing and marketing costs. The price of "bhusa" (wheat straw) varied from Rs 6.0 - 12/md of wheat.

Figure 8
Average Wheat Yield by Number of Irrigations in Cotton-Wheat Area

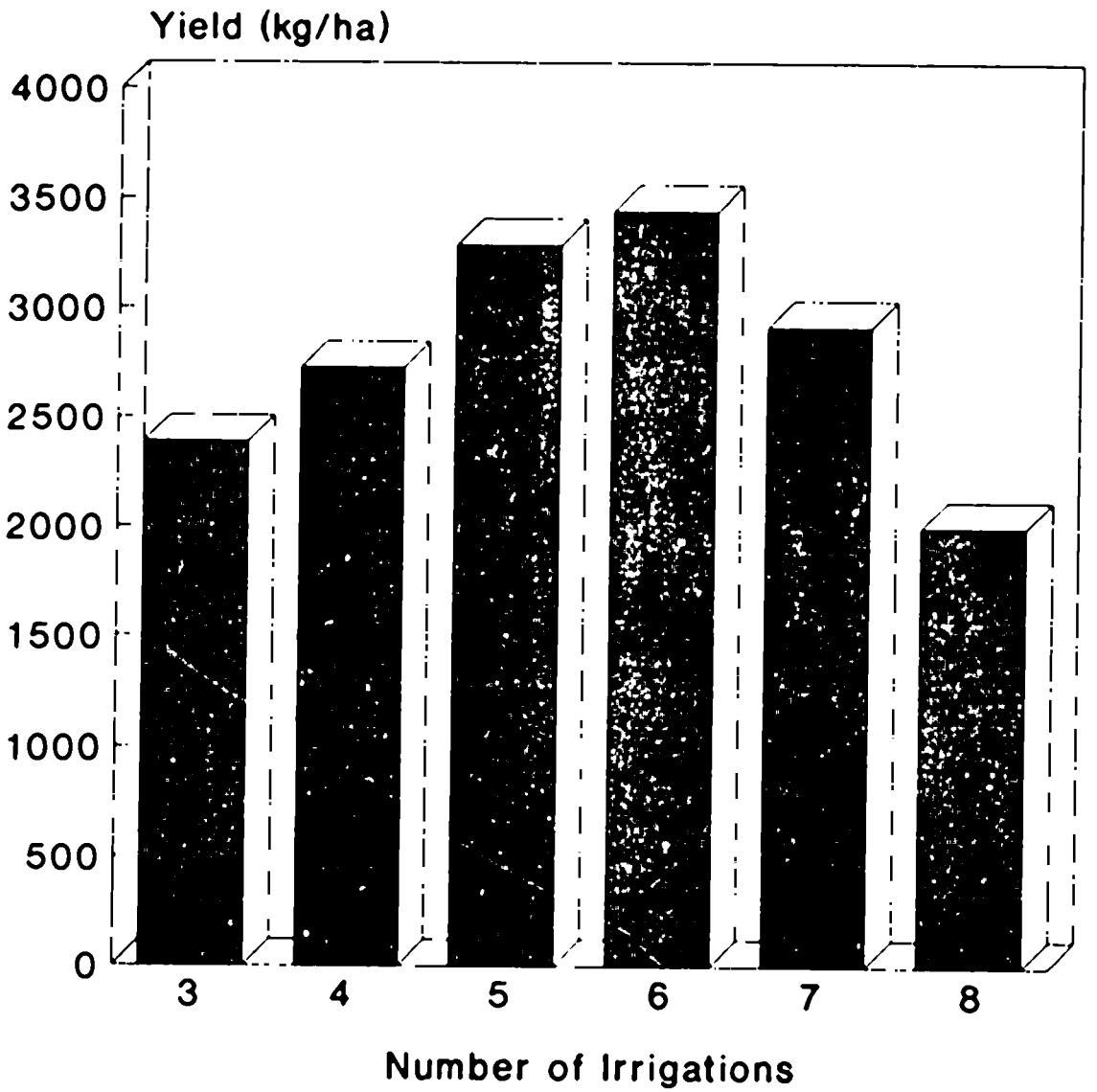


Table 14. Field Price of Wheat Received by Wheat Growers in Cotton-Wheat Areas of Sindh, 1989

Activity	Representative Cost	Remarks
Harvesting and transportation to threshing floor	2.5 mds/acre for average yield of 28 mds/acre	Varies from 2-4 mds/acre depending on the condition of crop
Threshing	5 kg/md	Varies from 4-6 kg/md
Labour for threshing	1 kg/md	Varies from 1-2 kg/md even provided by farmers
Transportation from threshing floor to market	3 kg/bag (2.5 mds)	Varies from 2-4 kg/bag, depending on market distance
Transportation of empty bags	Rs 1.0/bag	
"Tips" to agent	Rs 1.50/bag	
Usher	Rs 2.0/bag	
Wheat received price	Rs 80/40 kg	

- Net quantity sold = 29.2 kg per 40 kg harvested
- Net price (wheat price - cash cost = 80-1.80 = 78.20
- Field price of wheat = 78.20 x (29.2/40) = 57.0 per 40 kg
- Field price of wheat + Bhusa = 57.0+8.00 = 65 per 40 kg

Source: Interview with farmers and local grain buyers

Yield and Profit Analysis

Average Yields of Grain and Straw

The average measured wheat yields for the sampled fields was 3024 kg/ha. The official wheat yield for sampled areas for the year 1985-86 was 2.26 tons per hectare. Our sample may have over estimated yield, due to non harvested late planted fields.

Yields by soil type are given in Figure 9. It is clear that yields are higher where soil is good and growers and except lower yield in saline areas. However, even in the lighter soils yields are lower than in neighbouring district where wheat usually follows rice, sugarcane and fodder. The difference is in large part due to the difficulties of managing wheat in the rice-wheat rotation even on lighter soils.

Salinity is a major problem in the wheat fields of sampled area were further investigated by the incidence of salinity problem. Table 15 shows that 19% of the fields were rated as having "no salinity" problem and 11% had a "serious salinity" problem. Salinity problems were also correlated with wheat yields. Fields without a salinity problem produced 3652 kg/ha compared to 2105 kg/ha in fields with a serious salinity problem. No farmer was found who applied gypsum in the field.

Table 15. Frequency of Wheat Fields with Incidence of Salinity Problem and their Relation to Yield Cotton-Wheat Areas, 1989

Salinity Score	Percent of Fields	Average Wheat Yield (Kg/ha)
No salinity	19	3652
Some salinity	34	3076
Much salinity	36	2563
Serious salinity	11	2105

The average harvest index of 33% indicates that 2 kg of straw are produced for each 1 kg of grain. There was no difference in harvest index by variety, although it is generally assumed that the triple dwarf variety, Yecora will produce less straw than other varieties.

Variation in Wheat Yields

Wheat yields of the sampled fields ranged from 1332 to 4998 kg/ha with a coefficient of variation of 27%, one third of fields yielded less than 2000 kg/ha and only 17% yielded above 4000 kg/ha (Figure 10).

Figure 9
Wheat Yields by Soil Type in Cotton-Wheat Areas of Sindh

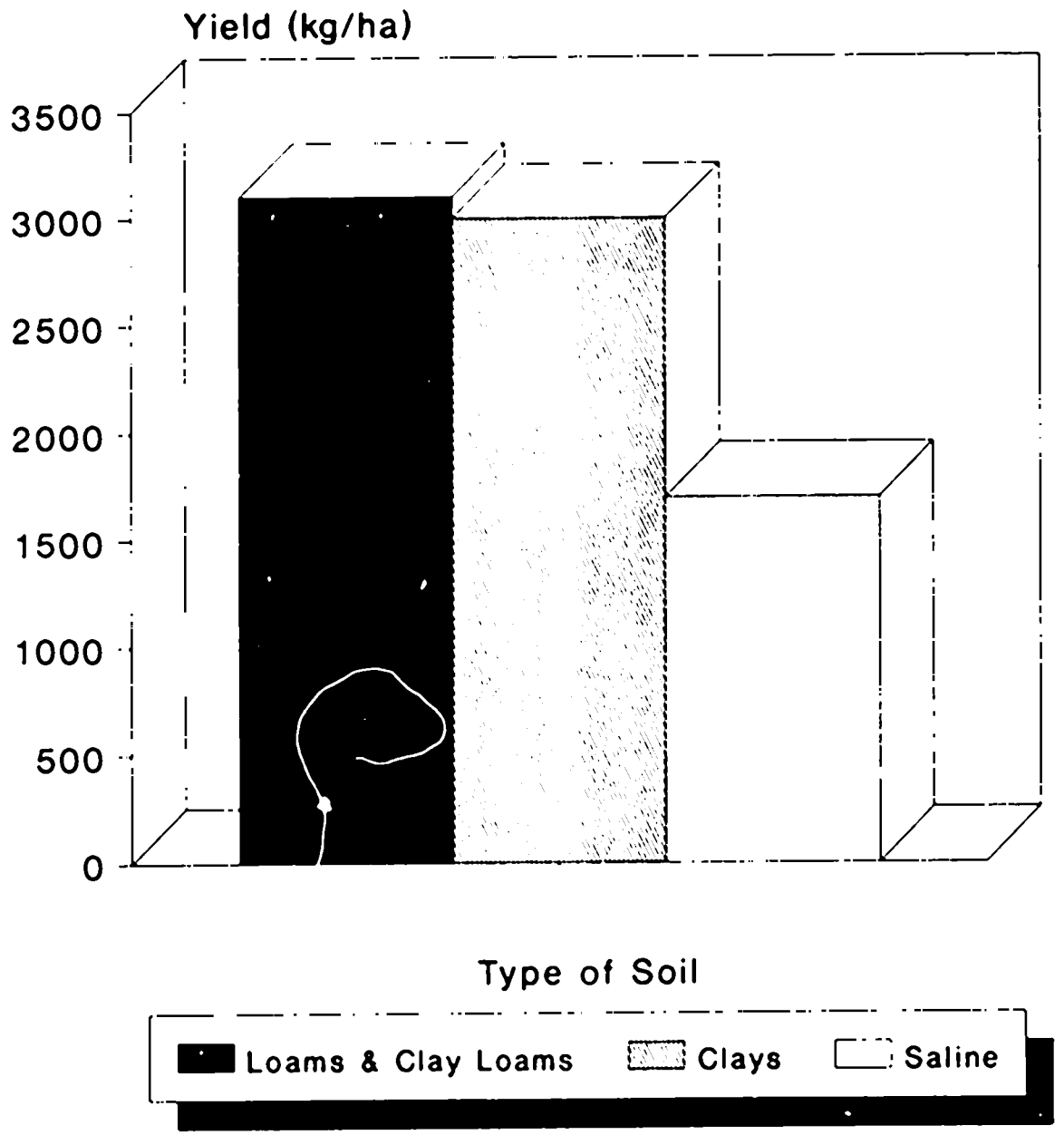


Figure 10
Distribution of Wheat Yields in Cotton-Wheat Areas of Sindh

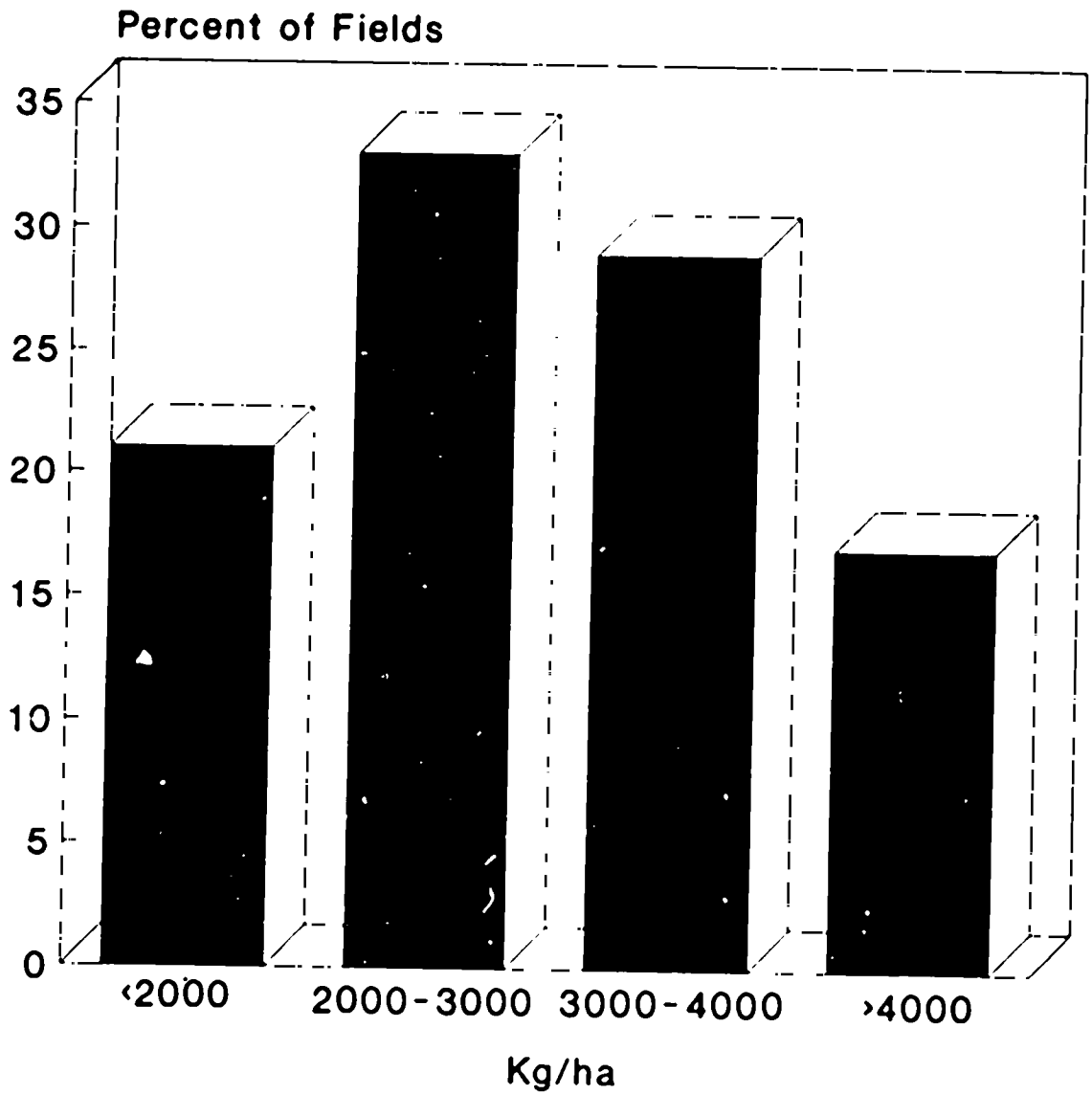


Table 16 illustrates the factors responsible for differences between low yielding and high yielding fields. Low yielding fields were defined as yielding less than 2000 kg/ha (21% of fields) and high yielding fields as greater than 3500 kg/ha (28% of fields). Major differences between low and high yielding fields are summarized below, and are useful in providing reasons for the variation of yields:

- To some extent high yielding fields were found among larger farmers having their own tractor and with access to the perennial canal water.
- Low yielding fields generally followed cotton, while high yielding fields followed fallow, (Statistically significant).
- The high yielding fields received one more ploughing for land preparation and more irrigations than low yielding fields.
- High yielding fields treated with more nitrogenous fertilizer compared to low yielding fields, but the same quantity of phosphorus in low and high yielding fields.
- In low yielding fields, serious weed incidence were recorded, compared to few weeds incidence in high yielding fields (Statistically highly significant).

Regression Analysis of Factors Affecting Wheat Yields

In order to determine the key factors affecting yields, multiple regression was undertaken. The dependent variable was estimated grain yield per hectare. All relationship were linear in all inputs, except for nitrogen fertilizer, for which a quadratic relationship with yield was hypothesised. The quadratic relationship was rejected, however, presumably because of problems of estimation caused by multicollinearity between explanatory variables.

Those variables hypothesised to affect wheat yields and their expected impact were:

- Number of ploughings (positive)
- Salinity of soil (negative)
- Soil type (positive, if clay loam)
- Previous crop (negative, if cotton)
- Fallow (positive, if fallow)
- Planting date (positive, if earlier)
- Number of irrigations (positive)
- Seed rate (positive)
- Nitrogen fertilizer (positive)
- Phosphate (positive)

All of these variables were included initially in the regression. However, on the basis of statistical and agronomic criteria, the "best" equation was:

Table 16. Summary of Major Differences in Farming System, Production Practices and Weed Problem in Low and High Yielding Fields, Cotton-Wheat Area, 1989

	Low Yielding Fields (< 2000 kg/ha)	High Yielding fields (> 3500 kg/ha)	Signi-ficance level
Percent of Wheat Fields	21	28	
Av. Wheat Yield (kg/ha)	1871	4191	
General			
Average Farm Size	8	13	.28
Percent 2-3 score salinity problem	21	4	.02
Percent Owner Operated Fields	7	3	.26
Percent Tenure Operated Fields	14	24	.26
Percent Planted "Wat Khair"			
Cropping System			
Percent Wheat After Cotton	10	9	.06
Percent Wheat After Fallow	5	15	.06
Production Practices			
Av. No. of Ploughing	4	5	.01
Av. No. of Irrigations	4	5	.34
Av. Dose of Total N kg/ha	115	123	.54
Av. Dose of Total P kg/ha	53	55	.25
% Planted Before Dec. 1st	19	28	.82
Percent Planted Recommended Varieties	11	12	.28
Percent Serious Weed Problem	17	2	.0001

YIELD (Kg/ha) = 2540 + 102 NUMIRRIG
(1.63)

+ 4.51 NITR + 175 DUMFALLOW - 964 DUMWEED
(1.01) (1.21) (-6.13)***

- 667 DUMSALT + 61.4 NUMPLOUGH
(-4.68)*** (1.18)

Adjusted R^2 = .472 F = 15.8***

n = 100 *** significant at 0.01 level

Where:

NUMIRRIG	=	number of irrigations (mean = 5.1)
NITR	=	nitrogen applied, kg/ha (mean = 102)
DUMFALLOW	=	1 if fallow, 0 otherwise
DUMWEED	=	1 if "many, serious", 0 if "none, some"
DUMSALT	=	1 if "serious", 0 otherwise
NUMPLOUGH	=	number of ploughings (mean = 4)

It is useful to interpret this result. On statistical criteria, the main variables determining yields are weeds and salinity. Nitrogen's relationship with yields is comparatively weak (and phosphorus's was sufficiently weak for it be excluded from the equation).

The results suggest that each additional irrigation adds about 100 kg/ha to yields. For nitrogen, each additional unit of N adds 4.5 kg/ha to yields. This suggests that the grain: nutrient ratio is low, and that fertilizer is not strongly constraining yields. Each additional ploughing added 60 kg/ha to yields, but also would have an impact on weed population. Weeds strongly affected yields with serious weed levels reducing the grain yields by 960 kg/ha. This suggests considerable gains in grain output can be achieved by weed control. Salinity is estimated to reduce yields by almost 670 kg/ha when "serious".

Overall, the regression analysis poses some interesting questions which can only be properly answered by a series of well-conducted trials in farmers' fields. For example, a series of simple herbicide trials could help establish the yield losses caused by weeds.

Profitability of Wheat Production

The costs and returns in wheat production are listed in Table 17 for two levels of yields: a) low yielding fields (< 2000 kg/ha) and b) high yielding fields (> 3500 kg/ha). The major variable costs are land preparation, fertilizer, water, harvesting and threshing. The costs and net returns showed a wide variation among the yield levels. The net return of low yielding fields covered only variable costs but they did not give a reasonable return on capital to farmers.

Table 17. Enterprise Budget for Low and High Yielding Fields Cotton-Wheat Area in Sindh, 1989

Activity	Rate Rs.	Low Yielding Fields < 2000 kg/ha		High Yielding Fields > 3500 kg/ha	
		Quantity ha	Value Rs/ha	Quantity ha	Value Rs/ha
Plough	175/ha	4	700	5	875
Plank	50/ha	2	100	3	150
Seed					
Own	80/40 kg	120 kg	240	-	-
Certified	100/40 kg	-	-	120	300
Fertilizer					
Total N	5.5/kg	115	633	123	677
Total P	5.0/kg	53	265	55	275
Irrigation					
Canal	50/ha	4	55	5	55
Miscellaneous					
Labour	25/day	4 days	100	5 day	125
Interest on Capital			100		117
Total Variable Costs			2193		2574
Land Rent	2000/ha/year	-	1000	-	1000
Total Costs			3193	-	3574
Gross Field Return					
Grain	57.0/40 kg	2000 kg	2850	3500 kg	4988
Straw	8.0/40 kg	4000 kg	800	7000 kg	1400
Net Return/ha, including Land Rent			457		2814
Net Return/ha, excluding Land Rent			1457		3814
Return on Capital %			73		164

As expected, the high yielding fields received higher levels of inputs and better land preparation and were generally planted after fallow. The net returns in high yielding fields were enough to give a reasonable return on capital to farmers. These results show the importance of cost reducing technologies in providing incentives to further expand wheat production in Sindh.

Defining Recommendation Domains

Recommendation domains are relatively homogeneous groups of farmers for whom we can make more or less the same recommendations. Major variation observed in the cotton-wheat are related to crop rotation, soil type, access to irrigation in water, and to some extent, farm size. The dominant criteria for stratification should be.

Cropping Pattern

Stratification on the basis of farmers who have wheat after cotton and wheat after fallow.

Soil Type

Stratification on the basis of soil type, distinguishing between (a) heavy clay soil (b) lighter clay-loam and sandy soil (c) soil with salinity and water-logging problems.

Access to Irrigation Water:

Stratification on the basis of farmers who have: (a) relatively more irrigation water because of perennial canals, (b) shortage of water due to location on the tail of the canal or water channel.

Farm Size:

Stratification by small and large farmers. This is associated with machinery ownership as well as access to inputs and information.

Location With Respect to Main Road or Town:

Stratification on the basis of (a) farmers who have market opportunities for sale of fodder or vegetables and (b) farmers who depend largely on wheat and cotton.

Major Problems and Their Solution

Late Planting of Wheat

One major problem in wheat is late planting. This is largely due to the wheat being planted after cotton. However, in some cases it is caused by scarcity of water. The solution to late planting of wheat is not easy. Two short run possibilities for alleviating the problem are:

Reduced turnaround from cotton to wheat through direct drilling with zero tillage, with the additional result that land preparation cost of Rs. 800 - 1000 per hectare would be substantially reduced. Direct drilling has been successfully tried in the rice/wheat area. In the cotton/wheat area, testing of the drill is now underway but more testing is needed to establish whether it will be effective and also to assess the implications for weed populations in the wheat crop.

Use of wheat varieties that perform well under late planting. At present Sonalika/Blue Silver have been recommended for late planting.

Use of Banned and Mixed Varieties

Forty eight percent of the wheat area was planted under banned and mixed varietal group, especially Yecora, Mexi Pak, Pak-70 and WL-711. Two ways are suggested to overcome this problem.

- Promote the benefits of new varieties to farmers by demonstrations and field days.
- Remove constraints in seed multiplication and seed distribution system in the province.

Insufficient Fertilizer Use

The survey data indicates that many farmers may be applying insufficient fertilizer, especially nitrogen. This suggests the need for careful measurement of fertilizer response under farmers' conditions. Trials should be conducted on fields under different conditions, notably:

- Planting wheat after cotton and after fallow at two planting dates.
- Planting wheat with adequate irrigation water and wheat with inadequate irrigation water supplies.

Over the longer term, additional research on fertilizer efficiency should include:

- Evaluation of response to phosphorus and carryover effects in the cotton-wheat cropping pattern.
- Checking of potassium or micro-nutrient deficiencies in heavily cropped fields (e.g. cotton-wheat each year).

Weed Problem

The serious weed problem were observed in 24% of wheat fields, causing an estimated yield loss of 960 kg/ha, against no weed in wheat fields. Simple herbicide trials should be carried out to test and demonstrate the use and method of application.

Late Harvesting

There was evidence that late harvesting in wheat due to shortage of hired labour during the peak harvesting period caused grain shattering and hence yield losses. This issue needs to be analysed by measuring yield losses and by assessing the existing labour market for wheat harvesting. This could serve as a basis for establishing policy regarding mechanical harvesting.

Overall this study suggests the need for a series of well-conducted on-farm experiments, following Aslam et al. (1989). These would form the basis of a set of recommendations for farmers that will better serve their needs than the current ones. Such experiments should be used for field days as soon as possible in order to extend new information to farmers of the wheat-cotton zone.

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Appendix-I

WHEAT CROP CUT SURVEY IN SINDH, 1989

	VARIABLE CODE
Sample_____Interviewer_____Date_____	1_____
Plot size(acres):_____	2_____
Plot Tenure:Owner___Tenant (25%)___Tenat(50%)___ Lease(Rs/acre)_____	3____4_____
Variety _____	5_____
Seed rate Kg/acre:_____	6_____
Seed source:Own__Neighbour__S/depot___Village shop__	7_____
Planting method:Drill___B/C(water)____B/C(dry)____	8_____
Planting date:Month/Week_____	9_____
No.of ploughing:Animal_____Tractor_____	10_____
No.of planking:Animal_____Tractor_____	11_____
Basal Fert.(Bags/acre):Urea___DAP__NP__AS__AN__	12___13__14___
Second Fert.(Bags/acre):Urea__DAP__NP__AS__AN__	15___16__17___
Third Fert.(Bags/acre):Urea___DAP__NP__As__An__	18___19__20___
Farm Yard Manure:Mds/acre:_____	21_____
No.of Irrigations:Canal_____Tubewell_____	22_____
Weed control:None__Hand___Chemical___Mechanical___	23_____
Harvesting:Family_____Hired_____other_____	24_____
Threshing:Animal_____Thresher_____	25_____
Previous crop:_____	26_____
Next crop:_____	27_____
Soil type:clay____Clayloam____Sandy____Saline_____	28_____
Salinity:Yes_____No_____	29_____
Extension service:Yes_____No_____	30_____

Farmer's estimatedyield:Mds/acre_____ 31_____

Bundle weight:Kg/sq.meter_____ 32_____

Grain weight:Kg/sq.meter_____ 33_____

Moisture content (%)_____ 34_____

Farmer's Name _____Village_____

Taluka_____District_____