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PARC/CIMMYT Wheat Paper No. 86-8

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Foreword

Barani or rainfed wheat is grown on one fifth of the wheat acreage in Pakistan but only provides ten per cent of the national production of this staple food. Any improvement in productivity in this agricultural area would ease the burden of feeding Pakistans' rapidly expanding population and allow more of the irrigated land to be used for other important commodity production.

Barani wheat production is more prone to risk through climatic constraints and as such farmers are more conservative in use of inputs on this crop. However, this report shows clearly that use of modern technology can increase and stabilise production in these areas at a cost profitable to farmers.

I am pleased that the present study concentrated on filling the gap that exists between research station activities and the situation that exists in farmers fields. This area of applied crop production research is a weak link in many agricultural programs but is an important component for development of the proper focus and recommendations that can quickly be adopted by farmers. The data were not only subjected to statistical procedures but also to economic analysis and the work involved both biological and social scientists working together collaboratively.

I would like to encourage this group of wheat scientists to help their provincial colleagues to conduct similar studies in other barani and irrigated areas to help tailor technology to the problems of our farmers. In this way wheat production can continue to increase profitably and meet our countries needs for this staple food.

June, 1986.

(Dr. Amir Muhammed)
Chairman
Pakistan Agricultural Research Council

Acknowledgements

The work presented in this paper are the team efforts of all the staff in the NARC wheat program from the head of the program to the lowly field worker. This applied wheat management research on farmers' fields is not, as some scientists believe, easy. The facilities are not readily on hand, work must be done in according to the farmers timetable and results must be visible to the farmer to gain his confidence. Many long hours in the field were required, often in the heat of April and May to get the work done accurately and on time. The staff should be commended for their ability to follow through and end up with this report.

Thanks must be given to Dr. Amir Mohammad, Chairman, PARC, Dr. Yousaf Chaudhri, Member, Crop Science and Dr. Anwar Khan, Director General, NARC for their support of this work. They not only allowed this work to continue but found time from their busy schedules to see the experiments in the field. We must also thank Haroon Abbasi, the CIMMYT Secretary who typed the many drafts of this report and Mr. Riaz the CIMMYT driver for the long hours he put in driving, transporting equipment and helping to keep the work going smoothly. Last but not least we must thank the farmers who allowed us to use their lands and waited for the experiments to be harvested before taking in their harvest.

Summary

1. This paper presents the agronomic data obtained on tillage, variety, fertilizer and weed control in the high and medium rainfall districts of Rawalpindi and Islamabad by the Wheat Program of NARC from 1983-85.

2. In 1983-84 and 1984-85, 8 and 20 locations, respectively, were chosen with 3-4 experiments at each location. Fields representing mera and lepara landtypes and wheat after fallow or maize were selected. Trials were mostly researcher managed and designed to obtain quantitative data on potential yields in the area.

3. Climatically both 1983-84 and 1984-85 were dry, hot years but drought stress occurred at different critical growth stages in each year. In 1983-84 stress occurred at the vegetative and grain filling stages whereas in 1984-85 stress occurred at the flowering stage.

4. Deep moldboard primary tillage gave 52% (1.3 t/ha) and 36% (0.7 t/ha) more yield than shallow cultivator tillage in 1983-84 and 1984-85, respectively. Better rooting associated with breaking of a compact layer below the plough layer was hypothesised as the major contribution to this increase in yield. More moisture, less weeds and less footrot disease were other contributing factors.

5. The cost of moldboard ploughing was equal or less than the cost of the farmers traditional practise of 8 shallow cultivator ploughings. Availability of moldboard ploughs and training in their proper use will be needed prerequisites for their adoption. Evidence is available that there is a positive residual effect of this primary tillage on subsequent crops following wheat that would make it an even more valuable contribution to increased productivity in the barani tract.

6. A nitrogen and phosphorous incomplete factorial experiment provided response surface data for calculation of economic recommendations for high rainfall barani areas using multiple regression coefficients. Mera lands need equal amounts of N and P with a significant N * P interaction evident on this land type. Lepara lands needed less N and P and there was no N * P interaction. In 1983-84, 0-45kg N-P_2O_5/ha was economic at a marginal rate return of 1.0 whereas the recommendations for mera and lepara land types at the same MRR of 1.0 in 1984-85 were 70-69 and 53-21, respectively.

7. Previous crop and ploughing affected the response curve with wheat after maize giving 858 kg/ha more yield than wheat after fallow and moldboard ploughing giving 449 kg/ha more than cultivator ploughing. However, these two practices did not interact with N or P and merely moved the response curve upwards by these amounts.

8. Pak 81, S19 (Junco "S") and Barani 83 were higher yielding and provided more stability in rust resistance than the predominant farmer variety, Lyallpur-73.

9. Weeds were not a serious problem especially in these two dry years. Broadleaf weeds could easily be controlled by the relatively cheap phenoxy herbicides 2,4-D, MCPP or MCPA or benzoic acid compounds like Dicamba but the farmer practise of mixing wheat and mustard would prevent this method of weed control.

10. Results suggest that barani wheat is a stable crop in the high rainfall areas since it provided good yields even in drought years. A discussion on the merits of favouring wheat over Kharif maize suggests that barani wheat is less risky than maize.

11. The report concludes with implications for future research. A recommendation is also provided for barani wheat in the high rainfall areas that should allow farmers to easily obtain 25-30 mds/acre, on average.

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Introduction

The difference in yields between those obtained by researchers and those obtained by farmers is referred to as a yield gap. Yield gap defines the difference between what is potentially possible in a specific location and what is presently being obtained by farmers.

The objective of an agronomist or any agricultural researcher should be to determine the reasons for this yield gap and to develop recommendations that can be adopted by farmers to lessen this difference in yield.

There is a tendency in Pakistan and many other countries for recommendations to be too general and wide based to be of much use to farmers. For example, the recommendation for fertilizer in the barani areas of the Punjab is 90 - 60 kg N - P_2O_5/ha irrespective of local differences such as land type, soil type, rainfall, previous cropping or input use. The recommendation is also not developed following economic analysis and merely gives an average rate that the scientists feel would be good for barani wheat farmers.

A more systematic research approach is needed that involves scientists of different disciplines (social and biological) and commodities, extension workers and farmers working together in specific agro-ecological areas. Research would focus on problems in specific areas with the objective of developing recommendations that can be adopted quickly by farmers. CIMMYT is encouraging this type of research in farmers fields and calling it onfarm research with a farming systems perspective (Byerlee et al. 1982). On-farm research is the part of crop production research that is the weak link in many agricultural programs. It does not substitute for on-station research but rather feeds back information to guide on-station research and verifies technology under farmer situations.

On-farm research follows a systematic approach of site selection, initial informal survey and description, more focussed formal survey and on-farm agronomic research. This paper presents the data for on-farm agronomic wheat research in the medium to high rainfall zones of the barani areas of Northern Punjab. It presents the data for the 1983-84 and 1984-85 rabi wheat crops and concludes with some recommendations for farmers and for future research. It is a second in a series that began with the data from the 1982-83 season (Hobbs et al 1983). Because of the variability in climate from year to year it is important to conduct agronomic trials over several years especially in rainfed areas. This variability should be considered in the recommendation in order to reduce the risk of failure under poor environmental conditions.

Material and Methods

Field Selection:

Fields were selected where farmers were willing to cooperate and where the previous crop was either fallow or maize. Wheat-maize-fallow-fallow or maize-wheat-maize-wheat are the two major cropping patterns in higher rainfall barani areas of the Punjab. Two major land types exist in the barani areas of the Punjab: mera land which is away from the homestead and receives less attention and less inputs, especially farm yard manure; and lepara land which is closer to the homestead, receives most of the farm yard manure and is more intensively cropped and managed. Wheat is usually planted after fallow on mera lands and after maize on lepara land in the higher and medium rainfall barani areas of the Punjab (Khan et. al, 1983).

In 1983-84, work continued in the medium rainfall areas around Daultala, Rawalpindi District and on IRDP Markaz land in Islamabad District. A total of eight locations were chosen and from three to four experiments were conducted at each site. In 1984-85 the work was expanded to not only include areas where previous experimentation was done but also farmers' fields in various parts of Islamabad District and areas around Fatehjhang, Attock District. A total of 20 locations were chosen and 50 experiments were planted and harvested.

Type of trials:

In both years trials were restricted to researcher managed trials where most of the important management practises were done by the researcher. In most cases the fields had been ploughed by the farmer before planting and then all other operations were done by the researcher. These experiments therefore provide quantitative data on potential yields in the area. Future work will verify the recommendations through more farmer-managed trials.

Inputs:

Seed and fertilizer input costs were provided by the researcher, and apart from the sampled areas taken for yield determination, the rest of the crop was given to the farmer. Except for the treatments under study all the other management practises were at recommended levels.

Tillage was done with a John Deere 60 hp tractor and planting with a Fiona single disc seed drill in 1983-84 and a New Zealand Seedmatic direct seed drill in 1984-85. Fertilizer treatments were broadcast by hand and incorporated with a cultivator prior to planting. Herbicides were applied with a CO_2

sprayer for treatments and a motorized backpack for general spray using a four nozzle teejet boom applying 250 litre water/ha through 8003 tips.

Data Collection and Design:

In both years a simple design was used in which the treatments were not replicated within the individual fields. Large strips were planted and four, two meter square samples were taken at random from each strip to determine yield. The number of spikes were counted in each sample and the threshed grain was sub-sampled, counted and weighed to obtain 1000 grain weight. Bhusa yields were determined by weighing bundles and subtracting grain weight. In both years all samples were cut carefully by hand using a one meter square quadrat to sample exactly the enclosed area.

All the data was analysed on an Apple IIe computer using various software packages (ANOVA II, Agrostat and REGRESS II).

The rest of this report is divided up into the respective trial types and ends with a section on recommendations and future research.

Climate

The 1983-84 and 1984-85 rabi seasons were different in respect to rainfall and temperature (Table 1 and 2). In Islamabad, the rainfall in 83-84 and 84-85 were 89 and 48%, respectively, of the average rainfall from October to April. The rainfall during these two rabi seasons was not evenly distributed resulting in moisture stress at various critical growth stages and resulting wheat yields were below normal. In 1983-84 there was a severe drought from October to mid February, plenty of moisture during booting and then moisture stress and high temperatures during the grain filling period. 1984-85 had drought from the booting to early grain filling growth stages of wheat development but sufficient early moisture and grain filling moisture. 1982-83 was a wet year with no moisture stress and 78% more rain than the 20 year average.

Table 1. Rainfall data for Islamabad in the 1983-84 and 1984-85 rabi seasons compared to the 20 years average

Month	Rainfall - (mm/month)			
	1963-84	1982-83	1983-84	1984-85
October	25	32	58	0
November	15	62	0	12
December	23	31	1	13
January	50	100	0	52
February	68	41	106	7
March	77	78	97	37
April	60	234	25	33
Total	**324**	**578**	**287**	**154**

These climatic differences also affected the responses of wheat to deep tillage, varieties and N:P fertilization.

The low rainfall in 1983-84 and 1984-85 also resulted in higher than average temperatures during the later stages of development (Table 2). This was more evident in 1984-85 when mean maximum temperatures in March and April (flowering and grain filling) were 4.8 and 2.0 °C higher than normal. In 1983-84, the mean maximum temperatures were 3.7 and 0.9 °C higher than normal in March and April.

Table 2. Maximum temperature (°C) data for Rawalpindi in the 1983-84 and 1984-85 rabi seasons compared to the 20 years average for February to April.

Month	Maximum temperature			
	Highest Mean Maximum	**Average Mean Maximum**	**Normal 20 yr average**	**Deviation from normal**
1983-84				
February	22.8	19.7	20.1	-0.4
March	33.3	27.3	23.6	3.7
April	36.1	30.6	29.7	0.9
1984-85				
February	30.0	23.7	20.1	2.9
March	31.7	28.4	23.6	4.8
April	38.3	31.7	29.7	2.0

Yields for 1983-84 and 1984-85 variety trials were 66 and 80%, respectively of the yields in the wet, cool year of 1982-83 (Table 8). Data from crop cuts in farmers fields in the same area where the experiments were placed were 1.90, 1.77, and 1.84 t/ha for the three years from 1982-83 to 1984-85, respectively (Hobbs et. al, 1986). This indicates that the stress in 1983-84 was more severe than in 1984-85 or that the stress occurred at a more critical growth stage.

Tillage

Methods:

Results in 1982-83 in barani areas indicated that deep primary tillage would increase yields on average by 15 percent. This primary tillage was done prior to the onset of the monsoon rains or just after the first rains in July. In 1983-84 four tillage treatments were studied at three locations:

(i) Cultivator - 7.5 cms deep

(ii) Subsoiler - 45 cm deep - the field was ploughed twice with the implement 30 cm apart in two directions at right angles to each other.

(iii) Chisel plough- 20 cm deep with one pass

(iv) Moldboard plough 30 cm deep.

All plots were given the same secondary tillage using a cultivator just prior to planting. In each of the three locations one field was selected for each tillage treatment. Soil samples were taken at 0-15 and 15-30 cm just prior to planting for soil moisture determination.

In 1984-85, based on the results of 1983-84, only the cultivator and moldboard treatments were used. The number of locations was expanded to 20 and at each location the moldboard and cultivator treatments were included in the same field by ploughing long strips of each treatment. Moldboard ploughing was done just after the first summer rains in fields with fallow, and in September in fields planted to maize. Soil samples were taken for soil moisture analysis just before planting. Secondary tillage was done by cultivator in all treatments just before planting the moldboard and cultivator plots.

Results:

The results from 1983-84 showed significant response to the use of moldboard plough. The moldboard plough gave on average 52% higher (1.3 t/ha) grain yields than the traditional cultivator across the three sites (Figure 1). All other tillage treatments did not differ significantly from the cultivator treatment.

Similar results were obtained in 1984-85 when the moldboard plough gave 36% higher (0.76 t/ha) grain yields than the traditional cultivator (Figure 1). This compares with a 15% increase in 1982-83 (Hobbs et. al, 1983) suggesting that the more stress the greater benefits in yield from good primary moldboard tillage.

Straw yield was also increased on average 20% due to moldboard ploughing during 1984-85 which is an important product used for animal feed in the barani area.

Tillers/m^2 and grains per spike were the two yield components responsible for the increase in yield in both years with the use of the moldboard plough (Table 3). Although 1000 grain weight was also higher in the moldboard treatment the figures were not significantly different from those with cultivator ploughing. This suggests that the benefits existed throughout the season since these two yield components are determined during the vegetative and floral initiation stages of growth.

Table 3. Effect of two tillage treatments on the yield and yield components of wheat during 1983-84 and 1984-85

Parameters	1983-84		1984-85		Average	
	MB	CU	MB	CU	MB	CU
Grain yield (t/ha)	3.80a[1]	2.50b	2.89a	2.13b	3.35a	2.32b
Tillers/m^2	273a	242b	210a	195b	242a	219b
1000 grain wt	39.2a	38.0a	39.9a	39.2a	39.6a	38.6b
Grains/Spike	35.6a	27.6b	30.2a	25.2b	32.9a	26.4b

MB = Moldboard, CU = Cultivator

[1] Figures followed by the same letter do not differ significantly from each other at the 95% level of confidence using a DMRT test.

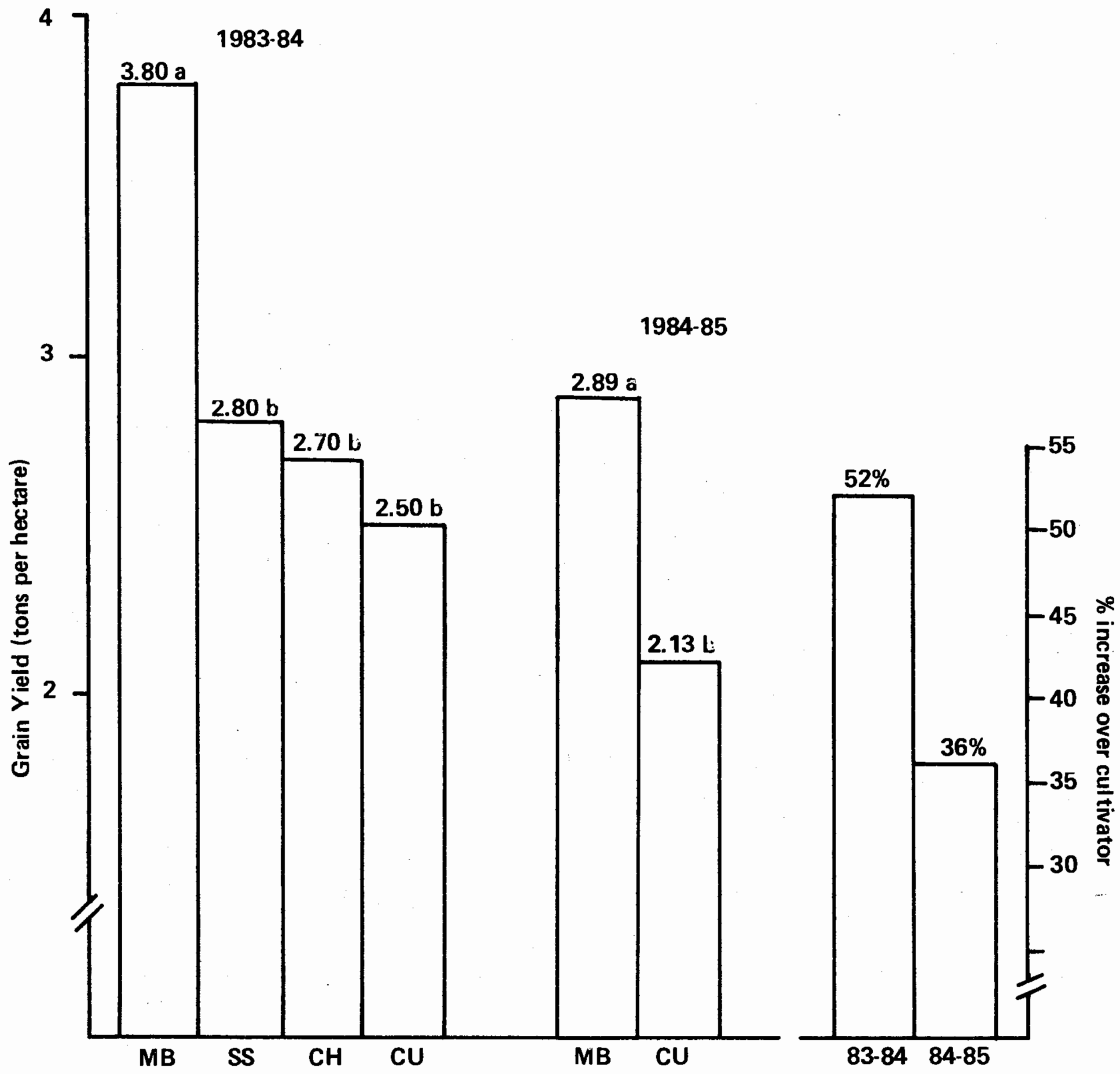

Fig 1. The effect of tillage treatments on the grain yield of wheat in Rawalpindi District in 1983-84 (average of 3 locations) and in Rawalpindi-Islamabad districts 1984-85 (average of 16 locations) and the percent increase of moldboard over cultivator in both years

Table 4 gives individual data for each of the 16 sites studied in 1984-85. At Hardoghar only a 3% increase in yield with the moldboard plough was obtained whereas at two of the Barakhu sites more than 100% increase in yield was obtained. There is also variability within a site since the third site at Barakhu only provided a 3.2% increase in yield from good primary tillage.

Table 4. The effect of 2 primary tillage treatment on the yield of Barani wheat at 16 sites in the 1984-85 rabi season in Islamabad and Rawalpindi districts.

Locations	Grain yield t/ha		Straw yield t/ha		% Increase over cultivator (grain)
	Moldboard	Cultivator	Moldboard	Cultivator	
Tarlie	1.87	1.21	3.92	3.08	54.0
Thandapani	2.96	2.32	6.21	5.90	27.6
Barakhu I	2.28	2.21	4.78	5.00	3.2
Barakhu II	2.34	1.08	4.91	2.74	116.9
Barakhu III	4.60	2.09	9.65	5.31	119.9
Golra	2.76	1.81	5.79	4.61	53.0
Hardoghar	1.64	1.59	3.44	4.00	3.0
Rawat	3.67	2.39	7.70	6.08	53.6
Rakhmor I	2.60	2.40	5.45	5.00	8.3
Rakhmor II	3.46	2.96	7.26	7.00	16.7
Daultala I	4.07	3.65	8.53	8.00	11.5
Daultala II	5.58	5.14	11.70	11.00	8.6
Fathejang I	1.78	1.35	3.73	3.44	32.3
Fathejang II	3.00	1.64	6.29	4.17	82.7
NARC I	1.96	1.19	4.30	3.16	65.2
NARC II	1.74	1.05	3.47	2.54	65.9
Average	**2.89[a]**	**2.13[b]**	**6.07[a]**	**5.06[b]**	**36%**

Several factors could be responsible for these yield increases with the moldboard plough and the variability from field to field:

1. **Better rooting:** In 1983-84, the soil and rooting profiles of all 4 treatments were dug at the Sukhmor site. Fig 2 is a drawing made from the photographs of the rooting profiles of the cultivator and moldboard plots. There was an apparent compact layer in the cultivator plot 10 cm below the soil surface and extending well into the profile. This compact layer was restricting root growth in the cultivator tillage treatment. In the moldboard treatment there was no compact layer and rooting was profuse throughout the first 30cm of soil. The subsoiler and chisel plots looked like the cultivator plots with respect to

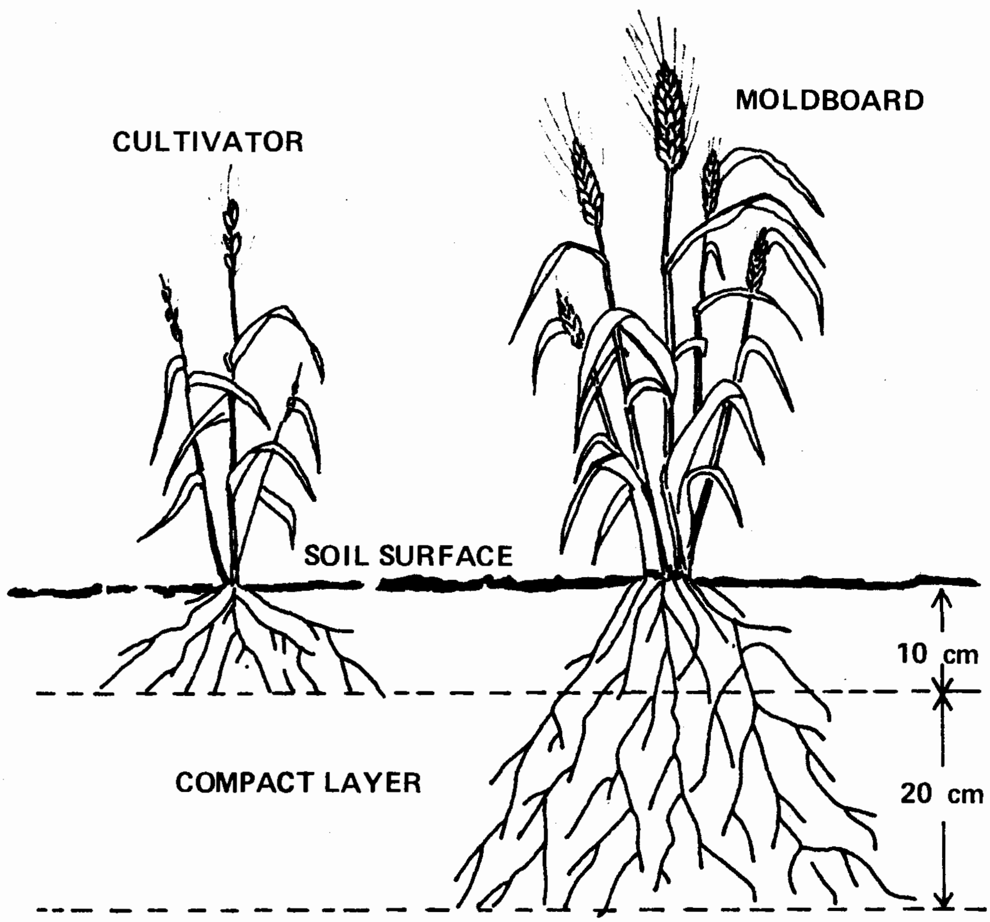

Fig 2. Wheat rooting profiles of the cultivator and moldboard ploughed treatments in February following drought in the 1983-84 rabi season, Rawalpindi, District

compaction and rooting. Better rooting would enable more infiltration of rainwater and make more moisture and soil fertility available for plant growth. This must be considered as the major reason for better growth.

The more passes a farmer makes with the tyned cultivator the more severe the compact layer will be below the ploughed surface. The introduction of tractors in the last decade without a primary tillage implement has probabaly contributed to this problem. During moldboard ploughing large clods several feet thick made up of very compact soil were brought to the surface in many of the treated fields. These clods were difficult to breakdown and farmers usually waited until after a rain to work the soil into a good seedbed.

2. **Better moisture:** Soil moisture data taken in 1983-84 (Table 5) indicated that soil moisture differences between tillage treatments were small. However, the 1984-85 soil moisture data (Table 5) showed greater moisture at the 15-45 cm depths for the moldboard plots. These differences between years could be due to differences in rainfall in September and October for the two years (Table 1). Sampling in 1984-85 was also done with more care than in 1983-84. The higher moisture contents in the moldboard plots in 1984-85 indicated that better water infiltration deeper into the soil profile resulted from loosening of the compact layer.

Table 5. Soil moisture percentage by tillage treatment just before planting wheat in the 1983-85 rabi season in barani area.

Tillage Treatment	Depth cm 0 - 15	15 - 30	30 - 45	Average
1983-84				
Cultivator	12.8	13.7	16.5	14.3
Moldboard	13.8	13.7	16.1	14.5
Chisel	14.5	15.0	17.7	15.6
Subsoiler	12.8	15.7	18.2	15.6
1984-85				
Moldboard	12.02	14.58	16.70*a	14.43a
Cultivator	11.74	11.22	10.36b	11.11b

*Figures followed by different letters are significantly different at 5% level using DMRT.

3. **Weeds:** Visually it was observed that the inversion of soil by the moldboard plough greatly reduced the weed population compared to the non-soil inverting tillage treatments. Weed growth was also less in both the kharif and rabi seasons in the moldboard plots. Less tillage was therefore needed in the moldboard plots to maintian a clean fallow, one of the major requirements for good moisture conservation.

4. **Diseases:** Dryland root rot, caused by ***Fusarium*** and ***Helminthosporium*** species, is a common disease of wheat in barani wheat especially in dry years or during drought. This disease was less prevalent in the moldboard ploughed plots (Table 6). Because of lower root rot incidence plant stands in the moldboard plots were better. Insect damage, mainly caused by termites feeding on the damaged dry rot roots were also reduced in the moldboard plots (Table 6).

Table 6. Effect of Tillage Treatments on insects and disease injury on wheat crop, 1983-84

Tillage	Plant examined (No)	Extent of Damage (%)		
		Root Rot	Termites	Total
Moldboard	1732	7.1	1.0	8.1
Cultivator	2522	19.3	10.3	29.6

Economics:

Data from a crop cut and farm management survey (Hobbs et. al, 1986) conducted in Rawalpindi District in 1983 and 1984 indicated that farmers plough their fields with a cultivator on average eight times before planting wheat. The values ranged from three to twenty two with the higher values recorded from fallow fields where there was no previous crop prior to wheat in the kharif season.

Data was also collected during the tillage operations on hours needed to complete each tillage operation and the quantity of diesel consumed (Table 7). Because of the effect of moldboard ploughing on kharif season weeds only two cultivator operations were needed to prepare the land just prior to wheat planting. The total cost of deep ploughing with moldboard plus two cultivations therefore, is less in terms of hours, total cost and fuel cost than traditional ploughing. This data does not take into consideration the depreciation value of owning a moldboard plough but we can conclude that the cost of both methods are essentailly equivalent and therefore any benefits in terms of extra yield from the moldboard are highly profitable.

Table 7. Total rupee cost[1] per hectare for moldboard and cultivator ploughing.

Tillage Operation	Number of Passes	Hour per ha	Total Time hr/ha	Rental cost Rs/hr	Total cost Rs/ha	Fuel use l/ha
(A) Shallow ploughing						
Cultivator	8	1.5	12	50	600	72[2]
Totals	**8**	**1.5**	**12**		**600**	**72**
(B) Deep ploughing						
Moldboard	1	5.5	5.5	60	330	41[2]
Cultivator	2	1.5	3.0	50	150	18
Totals	**3**	**7.0**	**8.5**		**480**	**59**

[1]Average of many sites during 1983-84 and 1984-85.
[2]Fiat 640 tractor

There was a difference between shallow and deep ploughing as far as time taken and fuel used per hectare. The Fiat 640 tractor took 1.5 hours per hectare with the cultivator and consumed 9 liters of diesel, while, with the moldboard the same tractor took 5.5 hours and consumed 41 liters. This works out to 6 and 7.5 l/hour, respectively for the cultivator and moldboard ploughing.

Discussion:

It can be concluded that the use of the moldboard plough for primary tillage in the barani areas results in a 15-52% increase in yield, depending on the rainfall, and that the cost of land preparation using this method is equal or less than that of the present farmer practise in the area.

The major constraint to its adoption is the availability of the implement although some farmers in Attock district (Ali Mohammad et. al, 1986) are using moldboard ploughs on barani land. Some manufacturers produce this plough in Pakistan but often materials are used that do not provide sufficient strength to withstand the rigours of this type of ploughing. A reversible moldboard plough would be a better implement since it helps reduce the problem of dead furrows and unlevel fields. The training of the tractor operator on proper adjustment of this plough is also essential for obtaining the benefits from this technology.

If it could be shown that moldboard ploughing was not necessary for every crop, but instead, provided residual benefits to following crops it would be an even more practical prospect for barani farmers. Research has already been started to obtain data to determine how frequently moldboard primary tillage should be done. Data from the NARC maize program indicates that there is a residual benefit from moldboard ploughing in wheat that is measured in the next maize crop (Haq Nawaz, personal communication). They planted maize for seed with recommended inputs on three fields moldboard ploughed for wheat in the previous wheat season. Net benefits were more than 1500 rupees/ha higher in the moldboard plots compared to the cultivator plots.

Small farmers may not be able to afford a moldboard plough, but since most farmers in Pakistan rent tractors for land preparation, what is needed is a local contractor with the proper implement and trained **operators** ploughing fields every 2 or 3 years.

Research is needed to determine if it is better to deep plough before maize and follow this with wheat or deep plough for wheat and follow it with maize. Deep ploughing may make this wheat-maize cropping pattern more feasible and less risky.

Assuming that compaction is a problem that is rectified by good primary tillage, farmers should be encouraged to adopt practises that delay the reformation of the compact layer after deep ploughing. Minimal tillage techniques can meet this objective. Minimal tillage is a recognized practise in many countries and will be an important management technology for the future in developing countries as fuel costs and equipment costs increase making it necessary to reduce costs of production if food is to be grown profitably but also at prices consumers can afford.

Fertilizer

Methods

Because of the possibility of a tillage times fertilizer interaction, an incomplete factorial design that used various N and P levels was superimposed on the tillage plots at all sites in both years. Strips that divided the plots into 8 or 9 equal sizes were broadcast with the appropriate amount of fertilizer at right angles to the direction of tillage. The incomplete factorial provided information on the nitrogen response at recommended P and the phosphorus reponse at recommended N. The treatments were as follows:

	P_o	P_1	P_2	P_3
N_0	*		*	
N_1			*	
N_2	*	*	*	*
N_3			*	

In 1983-84 the N levels were 0, 50, 100 and 150 and the P levels 0, 70, and 120. Potash was included as a ninth treatment at 50kg K_2O/ha together with recommended N and P levels.

In 1984-85 N and P levels were 0, 50, 100 and 150 and 0, 40, 80 and 120 kg/ha, respectively.

From the regression analysis of the fertilizer data the coefficients for the linear and quadratic functions were used to calculate the N and P recommendations at different marginal rates of return using the following equation:

$$N \text{ or } P = \frac{(MRR_i + 1) \times f_p/c_p - b}{2c}$$

where MRR_i = Specific marginal rate of return, f_p=fertilizer price, c_p = crop price, b=linear coefficient, c = quadratic coefficient.

Fertilizer and crop prices were used that existed at the time of analysis in 1985. Crop price was 1.75 rupees/kg, nitrogen was 5.60 Rp/kg and phosphorus 5.00 Rp/kg. The crop price used was the gross price and it was assumed that any loss due to harvesting and transport was compensated for by the value of the bhusa. A marginal rate of return was defined as the increase in net benefits which can be obtained by changing from one production alternative to another divided by the increase in variable costs for the same change.

Results:

The average wheat response curves from 13 barani experiments in the 1983-84 rabi season are shown in Fig 3 and 4 for N at constant P (70 kg P_2O_5) and P at constant N (100 kg N/ha). Individual site data are shown in Appendix A. Nitrogen response is quadratic in function but phosphorous only gives response upto the first 70 kg P_2O_5/ha.

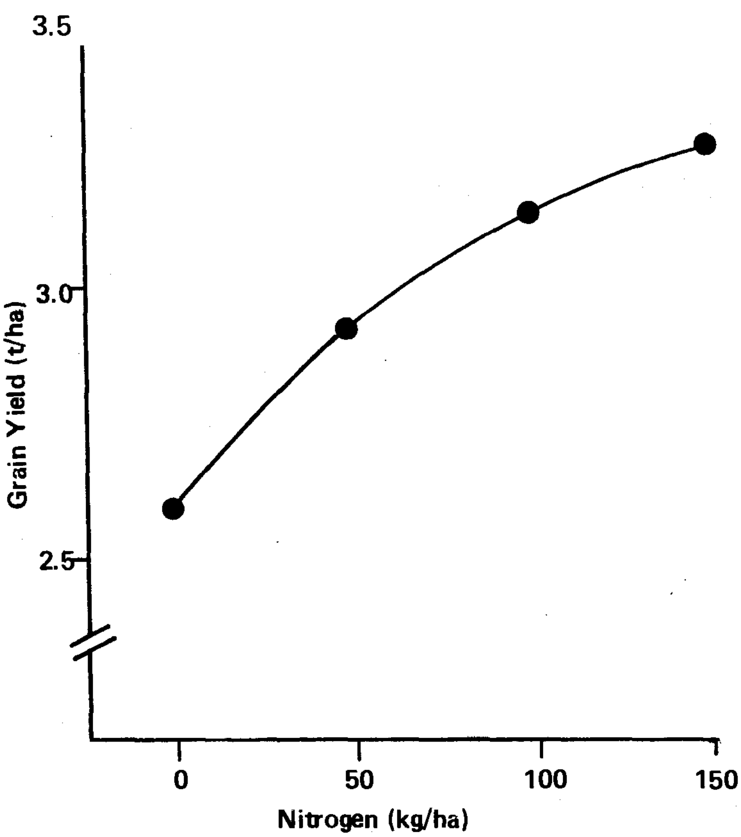

Fig. 3. Nitrogen response curve of 13 barani sites during 1983-84

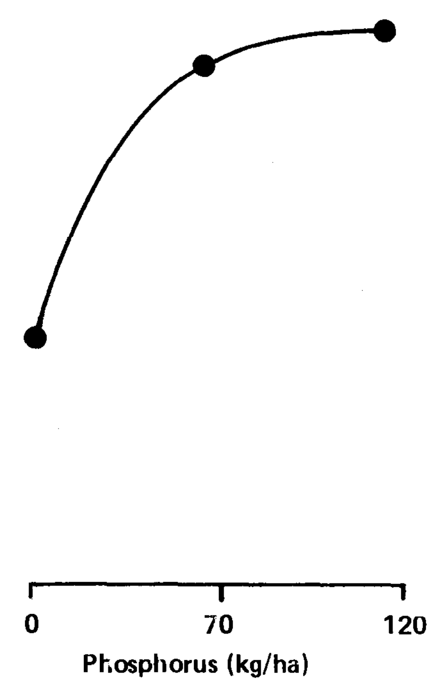

Fig 4. Phosphorus response curve of 13 barani sites during 1983-84

The data from the above 13 sites were subjected to regression analysis that included a dummy variable for deep and shallow cultivation in the equation. The 1983-84 equation was:

$$Y = 1729 + \underset{*}{5.57\,N} - \underset{ns}{0.01N^2} + \underset{***}{9.8\,P}$$

$$- \underset{ns}{0.045\,P^2} + \underset{***}{1166\,PL}$$

R^2	=	62.3%
Y	=	Yield (Kg/ha)
N	=	kg nitrogen/ha
P	=	P_2O_5/ha
PL	=	dummy variable where 0 = cultivator, 1 = moldboard ploughing.
*	=	significant 10%, *** = significant 1%

In 1984-85 more data was collected at each site and included information on land type (Mera vs Lepara), previous use farm yard manure, ploughing (deep vs shallow) and planting date. The average data from 24 experiments for N and P response are shown in figures 5 and 6, respectively. These curves also show the responses on mera and lepara land types and the average response over all land types. The nitrogen responses are quadratic for both land types. Phosphorous responses are quadratic for mera land but show little response on lepara land.

The data from these 24 experiments were combined for multiple regression analysis with the following result:

$$Y = 1184 + \underset{***}{14.45\,N} - \underset{**}{0.09N^2} + \underset{**}{11.47\,P} - \underset{ns}{0.077\,P^2}$$

$$+ \underset{***}{858\,PC} + \underset{**}{672\,LT} + \underset{***}{449\,PL} + \underset{13.7\%}{0.068\,N*P} - \underset{*}{6.04\,LT*P}$$

R^2	=	35% * = 10%, ** = 5% and *** = 1/% significance
Y	=	yield kg/ha
N	=	kg N/ha
P	=	P_2O_5/ha
PC	=	previous crop, 0 = fallow, 1 = maize
LT	=	landtype, 0 = mera, 1 = Lepara
PL	=	ploughing, 0 = shallow, 1 = moldboard
N*P	=	N x P interaction
LT*P	=	landtype x P interaction

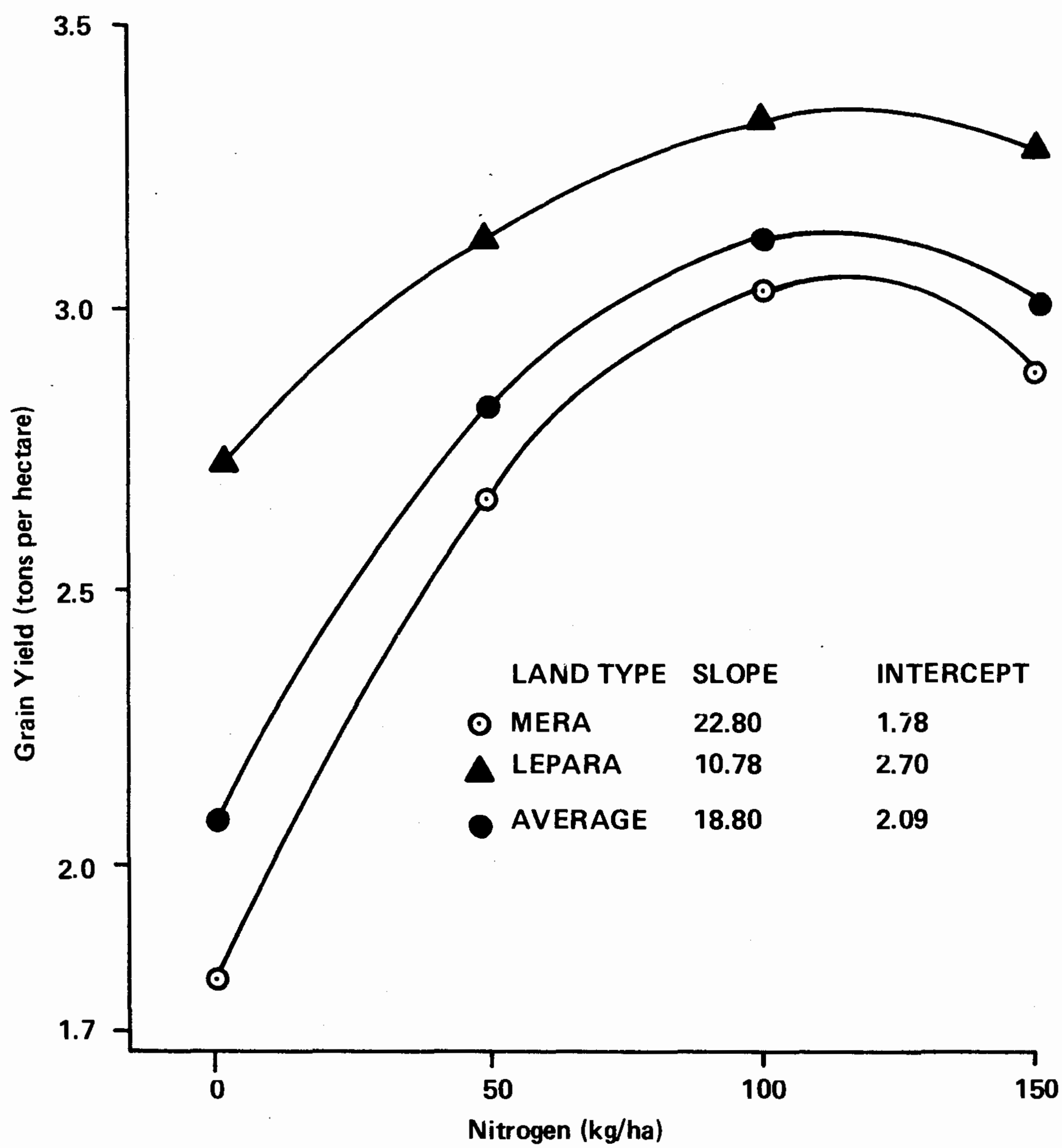

Fig 5. Nitrogen response curves for wheat at constant P (80 kg/ha) grown in barani areas during 1984-85

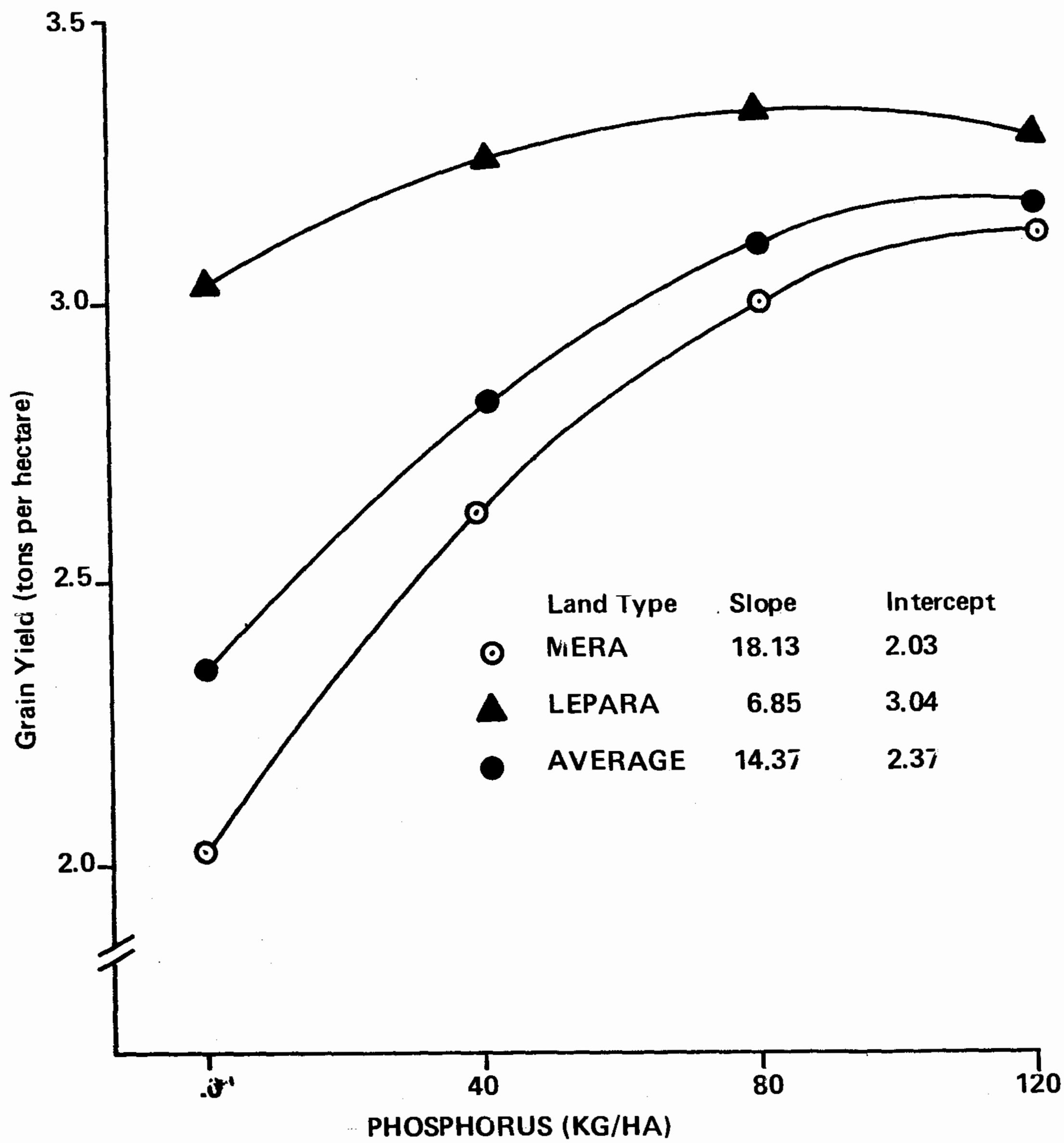

Fig 6. Phosphorus response curves at constant N (100 kg N/ha) for wheat grown in barani area during 1984-85

The only significant interaction was landtype and phosphorous which means the phosphorous recommendation will be different between land types. Although the NXP interaction was only significant at the 13.7% probability it was included in the equation and the calculation of recommendations. The equation also shows that N and P recommendations will be the same irrespective of ploughing or previous crop. The response curves are merely shifted upwards by 449kg/ha for moldboard ploughing compared to cultivator and 858 kg/ha for maize compared to fallow as the previous crop. This latter increase was unexpected since less moisture and fertility would be expected after maize. However, of the five out of 24 sites which grew maize before wheat only two were on mera land and probably insufficient data is available to explain this increase in yield. Rains were also good for germination and moisture was not a factor this year. Farmers also tend to choose their better fields for double cropping.

From the coefficients of the regression equations from both year's data it was possible to calculate the recommended N and P levels at different marginal rates of return using fertilizer and crop prices mentioned above. The data is summarised in Table 8. The year 1983-84 was a very dry year especially during the vegetative stages and obviously the response to N is flat (a coefficient of only 5.57) whereas in 1984-85 the drought occurred during flowering and the N response is much steeper (coefficient 14.4). Table 8 shows that nitrogen use is not very profitable in 1983-84 but use of phosphorus is. In 1984-85 nitrogen and phosphorus can be recommended although less phosphorus is needed on lepara land. This is because lepara lands benefit from higher doses of farm yard manure than mera lands. The higher organic matter would compete for sites on the clay minerals and make phosphorus more available. Some phosphorus may also be contributed by the farm yard manure. The N-P recommendation in 1984-85 at a MRR of 2.0 is identical to the fertilizer used by farmers in a barani area in Rawalpindi District (Hobbs, et. al, 1986).

Table 8. Nitrogen and phosphorus recommendations at different rates of return calculated from regression equations in 1983-84 and 1984-85 in barani areas.

Marginal rate of return (MMR)	N - P - K (kg/ha)		
	1983-84 All sites	1984-85 Mera	1984-85 Lepara
0.5	39 - 61 - 0	85 - 85 - 0	68 - 37 - 0
1.0	0 - 45 - 0	70 - 69 - 0	53 - 21 - 0
1.5	0 - 29 - 0	56 - 53 - 0	38 - 6 - 0
2.0	0 - 14 - 0	41 - 37 - 0	23 - 0 - 0

The soil analysis data for different locations was too variable between years to be of any use. Average available phosphorus levels in 1983-84 were 4.9 ppm compared to 14 ppm for 1984-85. On the same field at Sood Padana in 1983-84 and 1984-85 figures were 8.4 and 16.0 ppm, respectively. A study is needed to assess the accuracy of the labs where these samples were analysed before drawing conclusions on their results. Five ppm available P_2O_5 is considered low whereas 14 ppm is considered moderate. Any differences between mera and lepara land should also be ascertained. The soil samples are being analysed by a more reliable laboratory but data are presently not available.

Available potash levels were 151 and 183 ppm in the two years averaged over all sites. This indicates that there would be little response to potash. Available potash values ranged from 84 to 338 in 1983-84 and 72 to 396 in 1984-85. The range of 60 to 90 ppm is considered a medium rating for available potash. Potash was only applied in 1983-84 and at only two sites out of 13 was there a potash response. Average yields with and without potash with N and P at recommended levels were 3099 and 3058 kg/ha, respectively.

One interesting response was observed in the fertilizer trials on the mera land. Whenever nitrogen or phosphorus was applied alone the crop growth was not much better than the check plot without fertilizer (Fig 7). When the two elements were combined the wheat growth was excellent with an N x P interaction contributing 46% additionally to the yield. On lepara land this interaction was not observed (Fig 7) and this further suggests that the use of farm yard manure is making phosphorus more available in this land type. Yields were also more than one t/ha more on lepara land compared to mera land although this difference was reduced to 0.6 t/ha when N and P fertilizer was used. Further analysis of the data will determine the N x P x LT interaction which is probably significant.

Discussion:

The results outlined in this paper emphasise the need to develop specific recommendations for farmers with regards to fertilizer use. On mera land, nitrogen and phosphorus are essential for high yields with phosphorous just as important as nitrogen. On lepara land, less phosphorous is required than nitrogen and economically farmers do not need to use as much fertilizer. The results also show that there is no interaction between previous crop or method of ploughing and that the same recommendation can be used for both these situations. However, yields and response curves will be substantially higher where wheat fields are deep ploughed.

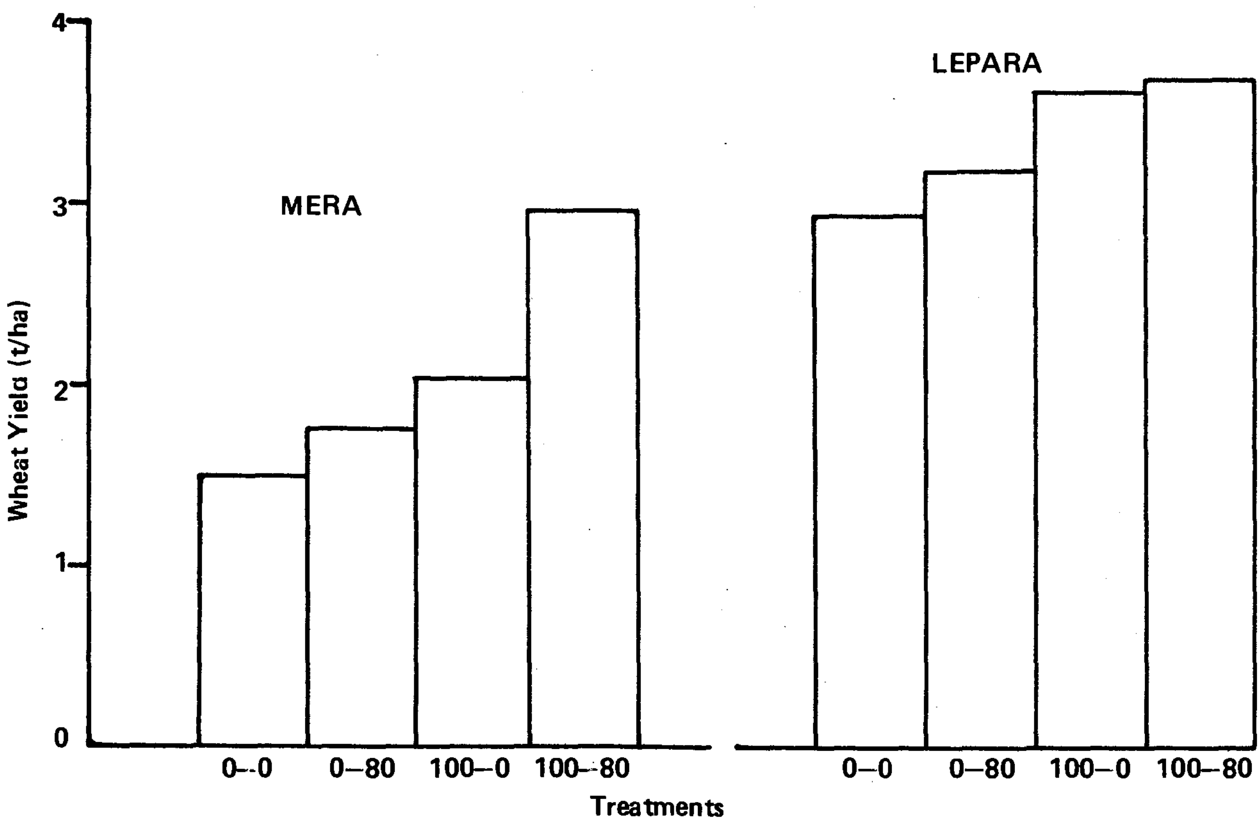

Fig. 7. The response of wheat to zero, nitrogen, phosphorus and nitrogen plus phosphorus over all sites on mera and lepara land in 1984-85 in the high rainfall barani tract of the Punjab

Potash did not provide any benefits that would justify its inclusion in the recommendations for this area. Soil tests also indicate that no response would be expected since all samples tested above 100-150 ppm available potassium.

With the increase in the use of seed drills by farmers (Hobbs et. al, 1986) there is scope for farmers to consider placement of fertilizer in the soil. Research is needed on this issue and to provide good quantitative data on ways to increase fertilizer efficiency through different methods of application. One logical recommendation would be to place the phosphorus and a little nitrogen (DAP or Nitrophos) in the soil at planting and topdress nitrogen during the vegetative phase if rainfall was good.

Research is also needed to determine the reasons for the difference between lepara and mera land and the role of organic fertilizer applied to these land types. Coupled with this research would be an intensive study on the role of micronutrients in increasing wheat yields.

Long term cropping pattern trials are needed to look at fertilizer management on a cropping pattern basis and the residual carryover and buildup of nutrients from one crop to the next. More fertilizer research is also needed for the drier parts of the barani tract. Data suggests that phosphorus may be more important than nitrogen in these areas.

Variety

Methods:

Pak 81, Barani 83, S19 (Junco "S") and the variety commonly grown by farmers, Lyallpur 73 were compared at each site in both years. At least one variety trial was conducted at each site.

Results:

The results of the varietal trials planted in Islamabad and Rawalpindi from 1982-1985 are summarized in Table 9 and Appendix B and C.

Table 9 **Average yield (t/ha) of 4 wheat varieties and % increase over LYP-73 in barani area of Northern Punjab.**

Varieties	Yield t/ha				% increase over LYP-73
	1982-83**	1983-84	1984-85	Average (82-85)	82-85
No of experiments	7	8	13	28	
PAK 81	4.40ab	2.90a	3.63a*	3.64a	18.9
S-19	4.60a	2.92a	3.58a	3.70a	20.9
Barani 83	4.20b	2.76a	3.25ab	3.40ab	11.1
LYP-73	3.65c	2.59a	2.93b	3.00b	-
Average	**4.21a**	**2.79b**	**3.35c**	**3.45**	

*Figures followed by the same letters are not significantly different at 5% level of significance using DMRT.

**Data from Hobbs et. al, 1983.

The wheat yields were significantly influenced by years, locations and cultivars. The average yields in 1984-85 were 20% (0.56 t/ha) higher than 1983 84 but lower than 1982 83 (0.86 t/ha) a wet year. This difference can partly be explained by the climatic differences between years but since different sites were used in each year a valid comparison cannot be made.

Discussion:

The best varieties in all the variety trials conducted in the barani areas in the past three years were Pak 81 and S19 (Junco "S"). Pak 81 was developed under irrigated conditions and is a recommended variety for these areas. However, the data suggests it does well in medium to high rainfed areas even when drought occurs. Pak 81 and S19 yielded significantly higher (18.9 and 20.9%, respectively) than the farmer variety Lyallpur 73. S 19 is a selection made at NARC but is yet to be released.

Barani 83 is released for the rainfed areas of the Punjab and although it did do better than Lyallpur 73 in all three years it suffered from shattering during the 1984 85 season at some sites at harvest. It is a taller variety liked by farmers for its bhusa.

The average yields of 5.88 t/ha at Sood Padana (Appendix 1) in 1984-85 and the 6 t/ha at the same site in 1982-83 (Hobbs et. al, 1983) probably represents the maximum potential yields for wheat in the barani tract.

As far as diseases are concerned Pak-81 is resistant to both leaf and stripe rusts while Barani 83 has shown susceptibility to leaf rust for the last two years with upto 20% susceptibility. S19 has some susceptibility to stripe rust. Lyallpur-73 is susceptible to stripe and leaf rust and to flag smut.

The performance of Lyallpur 73, the present farmer variety is good compared to local types (C591, C273, and other desi types). This variety is well adapted to dryland conditions and produces stable yields over time. New varieties like Pak 81, S19 and Barani 83 are available that outyield Lyallpur 73 and can provide more stability in wheat production because of their superior disease resistance. The major problem is multiplying seed of these new varieties and providing it to the barani farmers as quickly as possible. A village level, farmer to farmer, seed exchange and extension program could go a long way to fulfilling this need.

Breeders must also screen their germplasm under barani conditions and select the best yielders with suitable disease resistance and quality to maintain the flow of new varieties to farmers. High yield potential is an essential character in selection and all high yielding varieties identified from irrigated or low stress situations should be combined and tested under drought. The incorporation of winter blood in Spring x Winter and Winter x Spring material in the crossing block would also provide a good source of drought tolerance and high yield.

Weeds

Methods:

The following treatments were used at several sites in both years:

(i) Check plot no herbicide

(ii) DMA 6 (2, 4D) at 1.7 litre product/ha (1kg ai 2,4D/ha)

(iii) Buctril M (Bromoxynil + MCPA) at 1.3 litre product/ha (40% ai)

(iv) Banvil P (Mecoprop + Dicamba) at 4 litre product/ha (32.4 + 2.1% a.i).

(v) Dicuran MA (Chlortoluron + MCPA) at 2.5 kg product/ha. (40 + 20% a.i)

(vi) Tribunil (Methabenzthiazuron) at 2.0 kg product/ha. (70% a.i)

(vii) Tolkan or Arelon (Isoproturon) at 2.0 kg product/ha. (50 or 75% a.i)

Herbicides were applied as strips across the widths of the fields in plots where weeds were present and on fields adjacent to the other trial plots. Data was collected on yield and weed populations several weeks after application.

Results:

Weeds are not a serious problem in the rabi season in the barani tract unless rainfall is high (Hobbs et al, 1983). In the 1983-84 and the 1984-85 rabi seasons weeds were not present in abundance due to drought and moisture stress. *Fumaria parviflora*, *Euphorbia helioscopia*, *Asphodelus tenuifolius*, *Anagallis arvensis*, *Brassica campestris*, *Medicago polymorpha* and *Melilotus alba* were the major weeds present.

The data in table 10 show that herbicides influenced wheat yields by controlling the various weeds. However, the yield increases over control were very small and uneconomical, suggesting that in barani areas where weeds are present in low densities yields are not sufficently affected to warrant control. Only the cheaper phenoxy broadleaf herbicides can be considered as economic for weed control in the barani tract.

Table 10 Grain yield from two superimposed herbicide trials in 1984-85 in the barani areas.

Herbicide	Yield t/ha			% Increase over control
	Location I	Location II	Average	
1. Envoy	2.90*ab	2.63	2.76	4.9
2. Buctril M	2.20c	2.58	2.39	
3. DMA-6	3.18ab	2.25	2.71	3.0
4. Tribunil	3.00ab	2.95	2.96	12.5
5. Dicurran MA	3.10ab	2.60	2.85	8.4
6. Tolkan	3.45a	2.13	2.79	6.1
7. Control	2.73bc	2.53	2.63	-

*Figures followed by different letters are significantly different at 5% level using DMRT.

Discussion:

Broadleaf weeds can be a problem in wet years and if they are not controlled by rotation may build up to problem levels over time. Herbicides could be recommended to prevent buildups of weeds in future years especially where cropping intensity is increased and winter fallow is omitted from the cropping pattern. The phenoxy herbicides 2,4 D, MCPA and MCPP and the benzoic acid herbicide Dicamba are available and cheap in various formulations in Pakistan for control of broadleaf weeds. With the increase in the cost of farm labor and the exodus of labor from the region it is no longer feasible to control weeds in the barani tract by hand and use them for animal feed.

Research is needed on long term weed studies in cropping pattern trials and trials that minimize tillage operations. However, results must keep in mind that recommendations must be low cost if they are going to be adopted.

Cropping Patterns

Barani farmers in high rainfall zones of Northern Punjab practise double cropping of wheat followed by maize or jowar/bajra/pulse on lepara land or the same double cropping followed by a year of fallow on mera or areas with medium rainfall (Khan et. al, 1983, Supple et. al, 1986). The practise of growing two crops in two years with one year of fallow is locally referred to as "Dofasli dosala". Some farmers in the dryer barani tracts grow only one crop of wheat a year. In nearly all cases the wheat crop is considered the major crop and the kharif crop a bonus.

The question is often asked why farmers don't put more emphasis on growing kharif crops using monsoon rain rather than a rabi crop on residual moisture. One answer is obviously related to wheat being the food staple whereas the kharif crops are grown for fodder and some grain.

Data presented in this report and substantiated in crop cut studies in the same areas (Hobbs et. al, 1986) show that farmers' yield in the higher rainfall areas of the Punjab are quite stable and averaged 1.77 and 1.84 t/ha even in the dry years of 1983-84 and 1984-85 compared to 1.9 t/ha in the wet year of 1982-83. This data was obtained from more than 100 crop cuts/year taken from randomly selected fields in the area.

The maize and other kharif crops on the other hand are very dependent on monsoon rains which although providing more rain tend to be less reliable and come in heavy downpours and as a result, runoff is higher. For instance, in 1985, the monsoon rains did not start until mid-July. There was insufficient moisture before this date and so farmers delayed their maize planting. In 1982, monsoon rains were also late. In 1984, the monsoon rains finished in late August. This created drought problems for maize because at this time of the year temperatures and the evapo-transpiration demand of the maize crop are high.

The duration of the maize crop is also very dependent on the management given by the farmer. Most farmers use old, short duration varieties with little or no inputs. The crop is usually harvested by early October. When better varieties of maize are grown with recommended inputs for grain production, the crop duration is significantly longer and fields may not be available until early November. During this time rains are very uncertain, temperatures are high and the risk of failure of the maize crop is high.

Weeds are also more serious in the kharif season and the use of costly herbicide is recommended to obtain good grain yields. In other words, the farmers are probably correct in emphasising wheat cultivation, their staple food, on residual moisture plus winter rain rather than kharif crops.

The conservation of monsoon moisture is critical to wheat production. If sufficient moisture is available for planting wheat in October — November, plant stands are good and farmers can expect a reasonable harvest by the end of the year. Farmers conserve this moisture by fallowing the land prior to the wheat season and maintaining a clean fallow by frequent cultivation and planking of the land as rains occur. When maize or kharif fodder crops are grown before wheat less moisture is available for planting wheat and unless a rain occurs wheat stands will be poor or farmers may decide not to grow wheat after maize at all. This is even more important where farmers grow the improved varieties of maize for grain with recommended inputs since crop duration can be prolonged by as much as a month. In fact, the maize-wheat barani rotation is only found in the high rainfall zones of Northern Punjab or in wet years.

Mixed cropping

More than 75% of the barani wheat farmers in Rawalpindi District grow wheat mixed with Brassica (Hobbs et. al, 1986). The farmers use this mustard crop as fodder for their animals and pull out their daily fodder need for their animals from January onwards. Research has been conducted on this important issue in the last three years (Hobbs et. al, 1984) that shows that in a wet year mixing wheat and mustard is very profitable. In a dry year mustard growth is much less but does provide some green fodder without drastically reducing the wheat yield. Improvements to this system are needed and future work on wheat must include this important factor in recommendations. Planting mustard in lines may ease the harvest of fodder and reduce the damage to wheat but results show that total fodder production is lower with this practise. The whole strategy of weed control by herbicides is affected by the inclusion of mustard in the wheat fields.

Recommendations for Wheat

The following recommendations can be made for wheat in the high rainfall areas following the research outlined in this paper:

Land preparation:

Land should be ploughed by a moldboard plough 30 cm deep as early as possible after wheat harvest. This will depend on moisture availability (deep ploughing cannot be done if the soil is too dry) and whether a kharif crop is grown. If wheat follows fallow, moldboard ploughing should be done before or just after the first monsoon rains in the previous kharif season. If a kharif crop is grown this primary tillage should be done for the kharif crop. It should only be done after the kharif crop harvest if moisture is good for wheat planting. Deep tillage may only be necessary once every one to three years.

After deep ploughing the field should be cultivated and planked to break clods and left for planting wheat. One cultivator operation and planking should be given just before planting wheat.

Variety:

Pak 81 or Barani 83, and S19 if it is released are recommended over Lyallpur 73. Lyallpur can be used if seed of the other three varieties is not available. Seed rates should be 100 kg/ha and planting should be done by 'Pora' or seed drill at 20-25 cm spacing. If mustard fodder is necessary for farmers' animals the mustard should be planted along with the wheat.

Fertilizer:

On mera land, nitrogen and phosphorus should be applied in equal quantities at levels the farmer can afford. Up to 70 kg of each element per ha is economic with a marginal return of one. On lepara land the phosphorus dose can be reduced to 20 kg/ha and nitrogen to 50 kg/ha to obtain a marginal return of one. All the phosphorus and some nitrogen should be applied at planting and the rest of the nitrogen top dressed if there are good rains during the vegetative phase of growth. More nitrogen can be used in wet years.

Weeds:

These can be controlled by delaying planting and ploughing the first flush of weeds, hand weeding or by use of 2, 4D or MCPA formulated herbicides. Herbicides should be applied at recommended times listed by the chemical companies on their products but should not be used where farmers mix mustard with wheat.

Planting Date:

Wheat can be planted from the last week of October through November without affecting yield but depending on rainfall, the earlier one plants the higher the probability of sufficient moisture for germination. Many farmers plant in early October in the drier barani tracts to utilize this monsoon moisture.

If farmers follow these practises and use a reasonable amount of N and P fertilizer yields in the high rainfall barani areas should approach 25 - 30 maunds/ac or 2.5 - 3.0 t/ha.

Future Research

The following research is needed for wheat in the barani areas based on findings in this report.

1. Long term cropping pattern trials to quantify the effects of crop intensification on yields, moisture, weeds, pests and soil fertility, both macro - and micro-nutrients.

2. Long term experiments to determine the effects and residual carryover of deep primary tillage over time.

3. Experiments to determine the benefits and problems associated with introduction of minimal tillage technology following deep primary tillage.

4. Studies to understand the system of mixed cropping of brassica with wheat in terms of total production and fodder needs, and to develop recommendations that improve the efficiency of this system.

5. Response curve experiments for N and P fertilizer on farmers' fields that represent all rainfall and cropping zones of the barani tract. Determination of these curves should distinguish between land types (mera vs lepara) and soil types. Reliable data is needed over several years to sample different rainfall years (dry vs wet). Farm yard manure should be included

in the treatments to investigate its effect on fertilizer recommendations. Many of these trials should be farmer managed so as to obtain response curves under normal farmer management of other factors.

6. Studies to understand the reason for differences between mera and lepara land and the role of organic fertilizers.

7. Design and development of a better rabi drill for planting all barani crops and that will also allow fertilizer placement.

8. Studies on the efficiency of different methods of applying fertilizer.

9. Development of a breeding program to identify cultivars that can be planted earlier for better utilization of monsoon rains. These varieties for early planting (September or early October) would be very beneficial for drier barani areas. These varieties should either be long in duration to avoid frost damage during flowering or should flower before the chance of frost and enter grain filling during the colder winter months. Work being done to develop varieties for more tropical environments may help in this program since seedling heat stress and various seedling and leaf spot diseases are likely problems. Screening of germplasm just after the monsoon would quickly identify suitable material, if available.

Appendix A. Grain yield (t/ha) of wheat for different nitrogen levels at constant P_2O_5 (70 kg) and different phosphorus levels at constant N (100 kg) at 13 barani sites in 1983-84

Locations	Nitrogen kg/ha				Average
	000	050	100	150	
Barakhu	1.97	2.84	3.42	3.71	2.99c*
Tarlie	3.40	3.53	3.73	4.02	3.67b
Rawat	1.71	2.91	3.18	2.52	2.58de
Sukmor I	3.96	4.13	4.25	4.29	4.16a
Sukmor II	2.65	2.51	2.56	2.77	2.62d
Sukmor III	3.06	2.77	2.79	3.11	2.93c
Daultala I	3.17	3.90	4.18	4.03	3.82b
Daultala II	2.27	2.68	3.00	3.23	2.80cd
Daultala III	1.94	2.22	2.74	3.52	2.61d
Jatli I	3.20	3.99	4.30	4.15	3.91ab
Jatli II	2.19	2.18	2.39	2.81	2.39e
Jatli III	2.91	2.52	2.44	2.68	2.64d
Soodpadana	1.32	1.80	1.83	1.40	1.59f
Average	**2.60**	**2.92**	**3.14**	**3.25**	**72.98**

Locations	Phosphorus kg/ha			Average
	000	070	120	
Barakhu	2.51	3.16	3.88	3.18c
Tarlie	3.35	3.85	3.61	3.60b
Rawat	2.11	3.43	2.73	2.76de
Sukmor I	3.38	4.23	3.92	3.84ab
Sukmor II	2.88	2.72	2.43	2.68de
Sukmor III	2.37	2.38	2.83	2.53ef
Daultala I	3.05	3.80	4.01	3.62b
Daultala II	1.94	3.28	3.04	2.75de
Daultala III	2.61	2.80	3.19	2.87d
Jatli I	3.59	4.04	4.19	3.94a
Jatli II	2.11	2.24	2.68	2.34f
Jatli III	2.69	2.71	2.73	2.71de
Soodpadana	1.11	1.73	1.76	1.53g
Average	**2.59b**	**3.11a**	**3.15a**	

*Figures followed by different letters are significantly different at 5% level using DMRT.

Appendix B\ Grain yield (t/ha) of 5 wheat varieties at 8 locations in Rawalpindi district, 1983-84

Varieties	Barakhu	Tarlai	Sihala	Rewat	Sukhmor	Daultala I	Daultala II	Jatli	Average
Pak 81	1.73*b	4.59	2.58a	2.28	1.88	3.42a	3.37a	3.38	2.90a
S-19	2.47a	4.36	2.69a	2.24	2.48	3.16ab	2.81b	3.11	2.92a
Barani 83	2.10a	4.25	2.85a	2.46	2.13	2.88abc	2.82b	2.63	2.76ab
Lyp-73	2.29a	4.16	2.52ab	2.22	2.10	2.67bc	2.04c	2.68	2.59ab
ARZ	2.19a	3.65	2.16b	2.00	2.17	2.43c	1.86c	3.08	2.44b
Average	**2.16d**	**4.20a**	**2.56c**	**2.24d**	**2.15d**	**2.91b**	**2.58c**	**2.98b**	**2.72**

*Figures followed by the same letters are not significantly different at 5% level of significance using DMRT.

Appendix C Grain yield (t/ha) of 4 wheat varieties at 13 locations in Rawalpindi and Islamabad districts 1984-85

	Locations	PAK-81	S-19	Barani - 83	LYP-73	Average
		Yield t/ha				
1.	Tarlai	2.80ab*	2.88ab	3.15a	2.38b	2.80de
2.	Thandapani	3.91a	3.03b	2.40c	2.34c	2.92cde
3.	Barakhu - L1	2.41a	1.60b	1.50b	1.59b	1.71f
4.	Barakhu - L2	3.72a	3.54ab	3.22bc	2.90c	3.34cd
5.	Golra - L2	2.28NS	2.33	2.31	2.22	2.28ef
6.	Golra - L3	3.41b	3.51b	4.01a	3.49b	3.61c
7.	Hardoghar	2.60ab	3.09a	2.89ab	2.39b	2.74de
8.	Mora Fatima	5.53a	5.98a	5.40a	3.19b	5.02b
9.	Rakhmor	3.65a	3.63a	2.58b	2.98b	3.21cd
10.	Daultala	6.03a	5.48a	4.54b	5.41a	5.36ab
11.	Soodpadana	6.50a	6.41a	5.58ab	5.03b	5.88a
12.	Fathejang L-1	1.28b	1.76a	1.65a	1.89a	1.64f
13.	Fathejang L-2	3.30a	3.40a	3.00a	2.31b	3.00cde
Average 13 Location		**3.63a**	**3.58a**	**3.25ab**	**2.93b**	**3.35**

NS Non Significant
*Figures followed by the same letter are not significantly different at 5% level of significance using DMRT.

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