CONSTRAINTS TO LAND-AND WATER PRODUCTIVITY OF WHEAT IN INDIA AND PAKISTAN: A COMPARATIVE ANALYSIS

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Executive Summary

The present study focuses on constraints to wheat productivity in Pakistan. A review of achievements regarding the wheat productivity is performed at Pakistan level while constraints at farm level faced by the farmers are spotlighted. It covers environmental, agronomic, and economic constraints faced by the farmers for wheat productivity.

Wheat is the main rabi crop and being the staple food, it has a very high importance tag for achieving the food security for the country. It is cultivated in all four provinces of Pakistan, especially in Punjab and Sindh. Since 1975, about 27 percent increase in total area and 52 percent increase in yield per hectare for wheat are experienced. However, an increase of 33 percent in per capita availability of wheat has proved insufficient. Under these circumstances, import of wheat was the most obvious result mainly due to higher population growth rate for the same period.

In order to realize the dream of food self-sufficiency, government facilitated farmers regarding provision of high yielding varieties, improved seed, fertilizer at subsidized rate, irrigation water at cheaper rate than tubewell water, etc. however, these services were unable to reap the desired harvest mainly due to farmers' poor economic conditions and poor know how about the latest useful techniques and advancements. Additionally, low produce price at the time of harvest made farmers feel insecure about the investment they have done for inputs.

Improper land leveling combined with delay in sowing than recommended dates is resulting in lower production. Less than 50 percent of the farmers sow wheat by the recommended date mostly because of delayed harvesting of the kharif crops, and lack of equipment and machinery available for land preparation.

Inadequacy, inequity, and unreliability in water distribution are jointly affecting the farmers' irrigation schedules for the wheat crop. Water stress to wheat at critical stages, hampers the whole production efforts. Farmers having access to tubewell water usually manage to avert this problem, but this tolls an additional cost to them. Rainfall is also proved very valuable in helping farmers get away from crop water-stress situation and it is found that years experiencing rainfall during critical stages yield high wheat production than dry years.

With the spread of high yielding varieties and pressure for getting more crops and production from same piece of land, makes it inexorable to use more fertilizer to maintain the soil fertility level. However, due to higher cost of fertilizer, majority of the farmers use less than recommended dosages for the wheat crop production. Use of chemicals is mainly for overcoming the weedicides problem, but its use is not recommended if uneconomical. Chemical treatment of seed before sowing is almost negligible.

The devastating effect of salinity is more obvious at the tillering stage though it affects the plant at germination stage also. Wheat yield is significantly affected if water level rises up to one meter from the soil surface. Any further rise in water table severely affects the plant growth and thus, leads to significant decrease in yield and production. Improper drainage of excessive water is also an important factor affecting the wheat production.

Extremely high temperature is very much harmful for the wheat plant at different stages of growth. It can shorten the growth period and therefore, decrease in production if prevalent at flowering and grain filling stages. Light irrigations, selection of optimum time for sowing, selection of suitable variety, and use of mulch are recommended to avert risks.

Crop rotation is emerged useful for weed control and maintaining the soil fertility levels. As the cultivation of wheat crop in the same field for three or more years is found to increase the weed production, it is suggested this exercise should be discouraged. Any green manuring crop should be included in the crop rotation that will not only improve the soil structure and characteristics, but also improve the soil fertility and control the pest incidence.

Despite the continuous increase in supply of credit available, for farming community by the government, majority of farmers did not avail the opportunity in order to increase the input use according to the recommended levels. Complicated loaning procedures, high interest rate, and perception of the farmers about its use as risky, made it less useful than expected.

Policy packages and regulations are essential for promoting the wheat production to its potential level. Distribution of certified and improved seed, quality control, variety protection, discouraging the sowing of banned varieties, etc should be backed by proper policy package and regulations. Nothing can be more important than availability of irrigation water in adequate volume, reliably and at proper time. It requires improvement in water storage capacities, efficient, equitable, and reliable allocation system on the part of Government. On the other hand, to harvest more crops per available drop of water, farming community lacks know how and use of modern water management techniques for efficient utilization and proper conservation of water. Policies targeting the crop specific education and training to farmers would be able to change the present scenario.

A highly educated staff, with new ideas and understanding of the diffusion process is required for disseminating the information right up to the base level as the role of extension services needs to be updated as an information providing agency. More resources and better utilization of formal and informal media for enhancing the diffusion of information is the need of the time.

Keeping in view all above, it can be concluded that though it may be difficult to increase more area under wheat cultivation, it is possible to improve the input use behavior of the farming community in order to scythe potential harvest. By equipping the farming community with modern tools and know how, it is possible to tap the unachieved potential of wheat crop from the same croplands.

CONSTRAINTS TO LAND-AND WATER PRODUCTIVITY OF WHEAT IN INDIA AND PAKISTAN: A COMPARATIVE ANALYSIS

Supplement 1:

Major Constraints To Wheat Productivity In Pakistan

1. OVER VIEW OF WHEAT CROPPING IN PAKISTAN

Being a staple food, wheat production is distributed to all the four provinces of Pakistan. Punjab alone contributes 70-75 percent to the total annual wheat production.

1.1 Area, Yield, and Production

Figure1 (Pakistan, 1986, 1994, 1996, 2000) shows the distribution of land utilized for different crops in rabi. It clearly shows that about two-thirds of the total farms in rabi were under wheat crop. It is also alluring to note that the smaller the farm size, higher the percentage of area under wheat. Moreover, as the size of the farm increases, the area under wheat crop decreases. However, the data shows that for all farm sizes, more than 50 percent of the area was under wheat crop during the rabi.

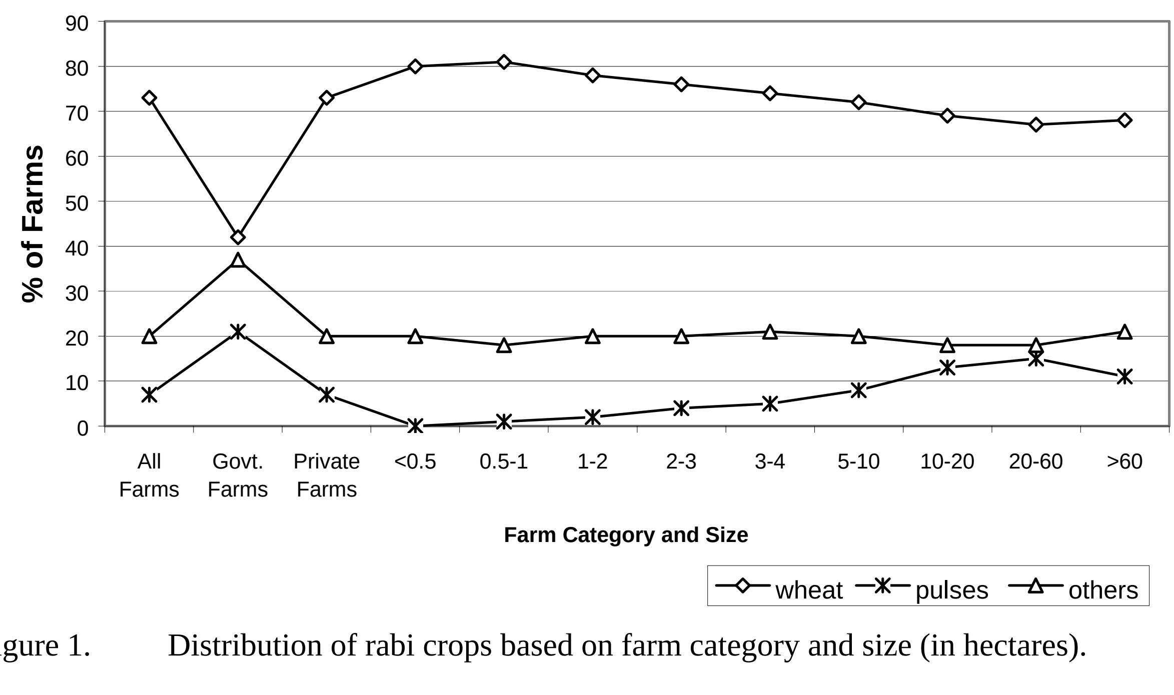

Figure 1. Distribution of rabi crops based on farm category and size (in hectares).

Time series data of cropped area in Pakistan is shown in Figure 2 (Pakistan, 1986, 1994, 1996, 2000). Total cropped area has increased from 18 Mha in 1975-76 to 23 Mha in 1998-99 claiming about 28 percent increase in total. Area under food grains[1] has increased from about 10 Mha to 13 Mha for the same period with a total increase of 30 percent. Similarly, the area under wheat crop alone has increased from 6 to 8 Mha for the same period. It claims an increase of 25.75 percent since 1975-76 to 1998-99.

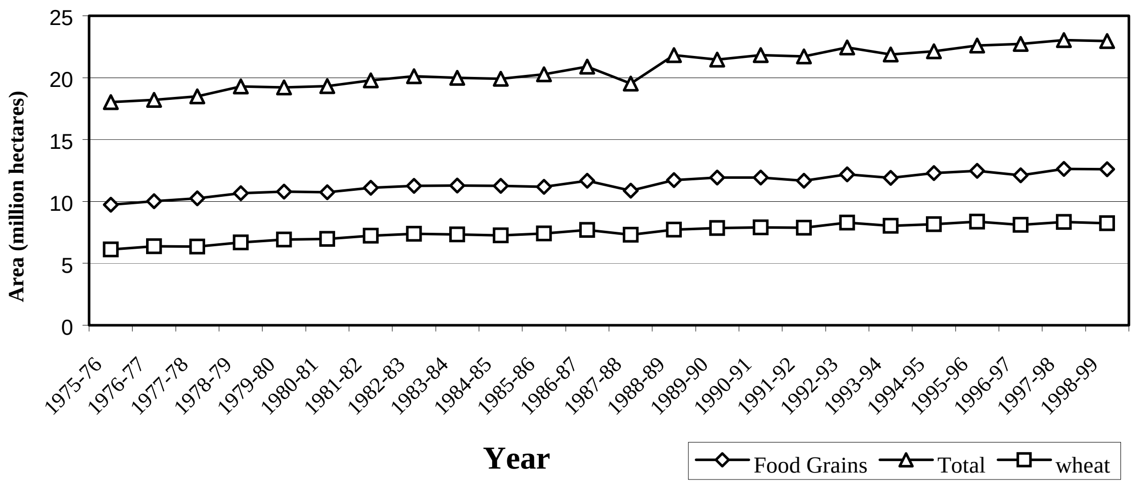

Figure 2. Distribution of cropped area with respect to food grains in Pakistan.

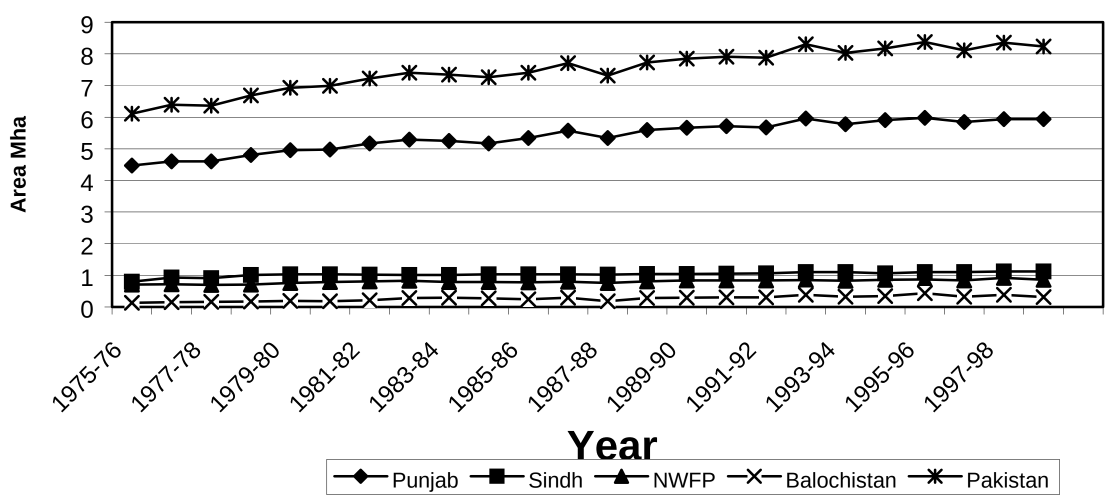

Figure 3. Distribution of area under wheat crop in Pakistan.

Figure 3 (Pakistan, 1986, 1994, 1996, 2000) shows the distribution of the area under wheat segregated with respect to provinces for the period 1975-76 to 1998-99. It is clear from the Figure that over time, major wheat growing province is Punjab while Sindh, NWFP and Balochistan contribute smaller share to the total area for the production of wheat. During this

[1] Food grains = Wheat, Rice, Jowar, Maize, Bajra, and Barley

period, in Punjab province, an increase of about 32.7 percent is recorded. Punjab alone shared about 73.17 percent to the Pakistan's total area under wheat in 1975-76 that decreased to 72.11 percent during 1998-98. An increase in area under wheat is also evident in other three provinces though its magnitude is significantly small as compared with increase in area in Punjab.

Figure 4 (Pakistan, 1986, 1994, 1996, 2000) depicts the wheat production overtime with respect to Pakistan and different provinces. In 1975-76, Punjab contributed about 75.54 percent of the total produce in Pakistan. Due to increase in production of wheat in other three provinces, this share was decreased up to 73.91 percent in 1998-99. It is also worth noting that troughs and crests in Pakistan's wheat production line are mainly due to fluctuations in the wheat production in Punjab. Other three provinces show an increasing trend over time, but the amplitude of this increase in terms of Pakistan's total output is small as compared with Punjab.

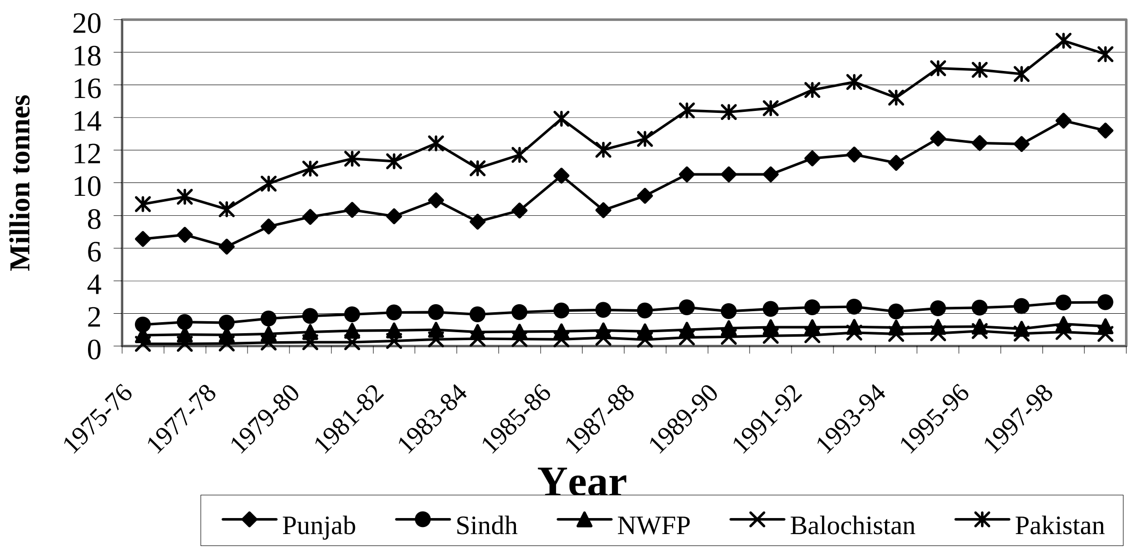

Figure 4: Distribution of wheat production in Pakistan.

Hobbs and Morris (1996) discussed that wheat yield take off occurred in 1967 in Pakistan although it was less impressive as compared with other South-Asian countries. Afterward, further increase in wheat yield was marginal in nature.

Figure 5 (Pakistan, 1986, 1994, 1996, 2000) depicts an interesting situation regarding yield (kg/hectare) in Pakistan and in its provinces. Though Punjab contributes almost two-thirds to the total wheat produced in Pakistan, but most of the times, farmers of Sindh province were getting the maximum yield than other farmers of other provinces. Interestingly, since 1993-94 to onward, the farming community from Balochistan is getting highest wheat yield. The farmers of NWFP are also getting much higher yield as compared with their initial yield level in 1975-76, but still they are at the lower threshold as compared with other provinces.

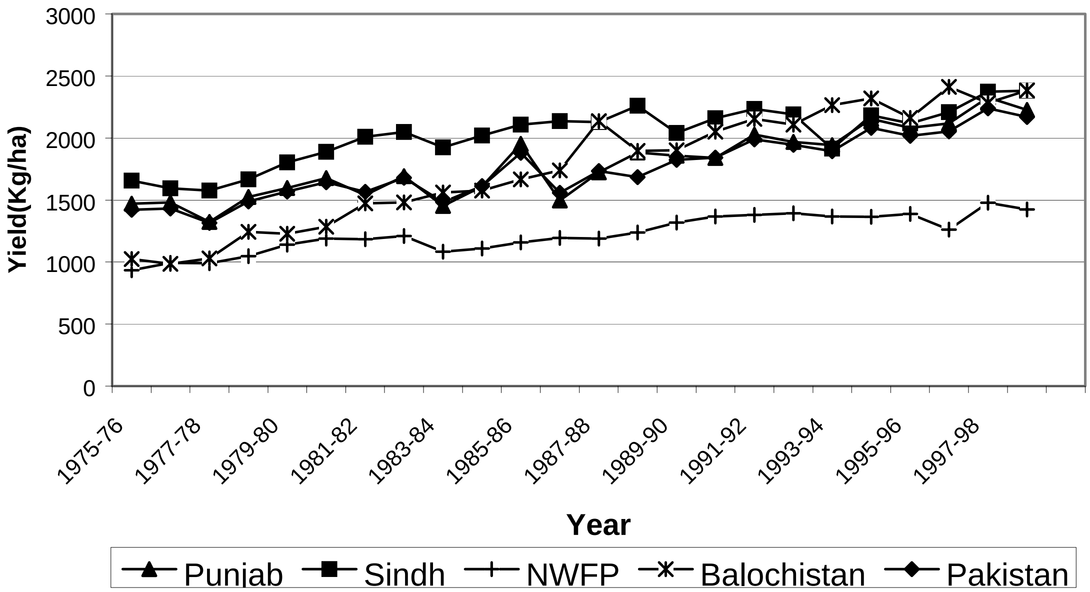

Figure 5: Distribution of wheat yield in Pakistan.

Despite 105 percent increase in total wheat produced during 1998-99 as compared with the total wheat produced in 1975-76, Pakistan is unable to show an impressive increase in per capita availability of wheat available for the masses as shown in Figure 6 (Pakistan, 1986, 1994, 1996, 2000). In 1975-76, archives show that per capita availability of Wheat in Pakistan was about 106 kilogram/annum where as it was about 141 kilograms/annum in 1998-99. Despite amplification of wheat produced in the country, amount of wheat available was insufficient to meet the demand of the population. Consequently, wheat had to be imported as shown in Figure 7 (Pakistan, 1986, 1994, 1996, 2000). This was a embarrassing situation for an agricultural country that it could not meet its own wheat grain demands. For the period of 1975-76 to 1998-99, country experienced only four such years when it did not import any wheat.

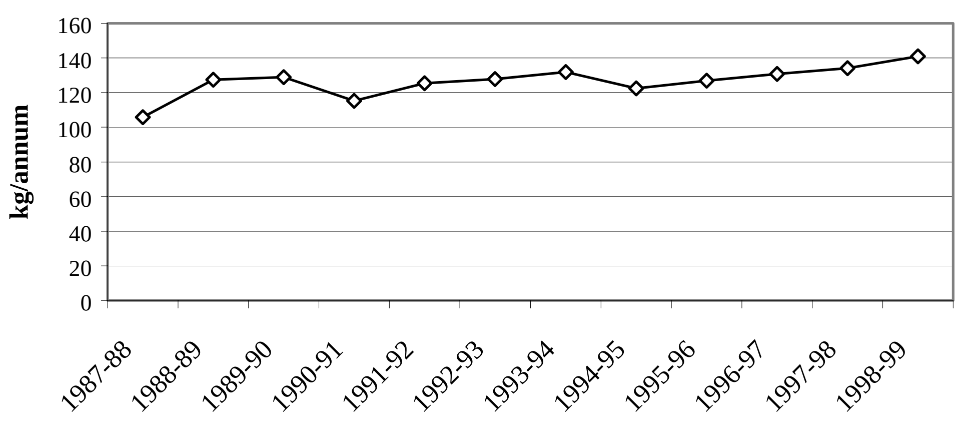

Figure 6. Annual per capita availability of wheat in Pakistan.

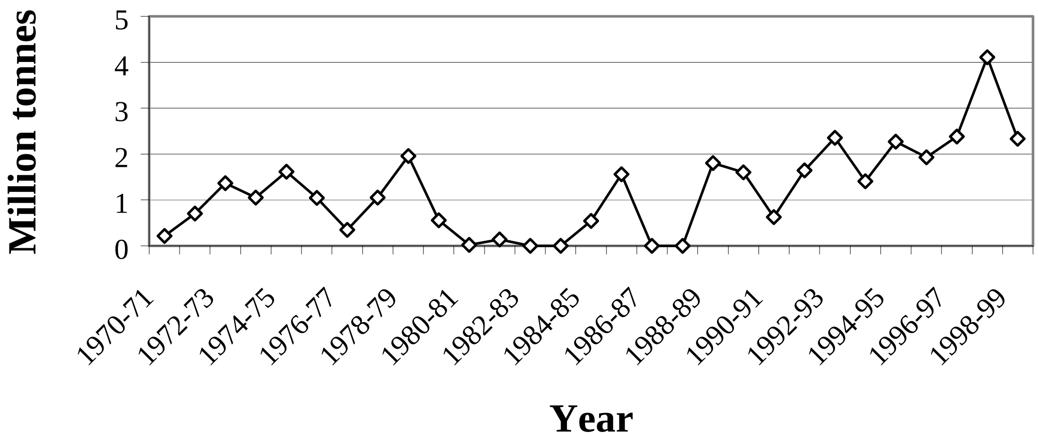

Figure 7. Annual wheat import in Pakistan.

1.2 Soils

Aslam (1998) reported that majority of soils in the Indus basin are coarse to moderately fine textured and suitable for irrigated agriculture. Salinity and sodicity caused the poor yield performance for the wheat crop. With rise in salinity level, significant wheat yield reduction was reported. It was found that in slightly saline soils, yield reduction was almost 36 percent than in normal soils. In moderately saline and highly saline soils, the extent of yield reduction was about 68 percent and 84 percent as compared to yield in normal soils, respectively.

Doorenbos et al. (1979) reported that wheat could be grown on a wide range of soils, but medium textures were preferred. It was suggested that growing of wheat on peaty soils containing high sodium, magnesium or iron should not be practiced. The optimum pH range for wheat was found from 6-8. Wheat was found relatively tolerant to a high groundwater table. However, with a rise of groundwater table to 0.5 m for long periods, the yield decrease could be 20 to 40 percent. Crop was also found moderately tolerant to soil salinity, but ECe[2] should not exceed 4 dS/m[3] in the upper soil layer during germination. Yield decrease due to salinity was estimated as 0, 10, 25, 50, and 100 percent at ECe of 6, 7.4, 9.5, 13, and 20 dS/m, respectively.

1.3 Varieties

The annals of area under high yielding or modern varieties for wheat in Pakistan show that majority of the farmers were adopting high yielding varieties. In 1975-76, about two-thirds of the area was covered by high yielding varieties of wheat that increased and reached up to 94 percent in 1998-99 as shown in Figure 8 (Pakistan, 1986, 1994, 1996, 2000).

A breakup of land under high yielding varieties with respect to different provinces of Pakistan shows that farmers in Punjab were more inclined towards adoption of modern varieties. This situation is depicted in Figure 9 (Pakistan, 1986, 1994, 1996, 2000).

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[2] Electrical conductivity of saturation paste extract.
[3] dS/m means deci-siemens per meter.

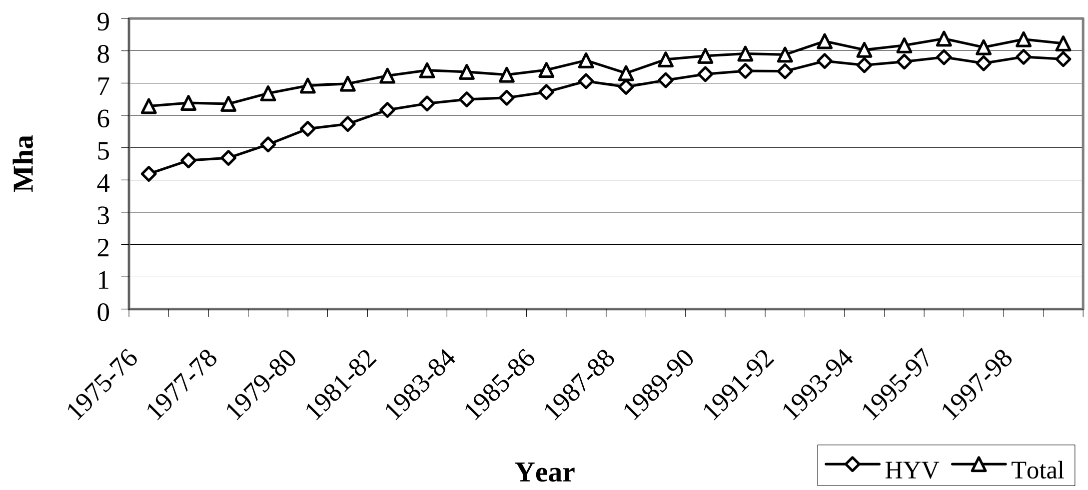

Figure 8. Distribution of area with respect to varieties of wheat in Pakistan.

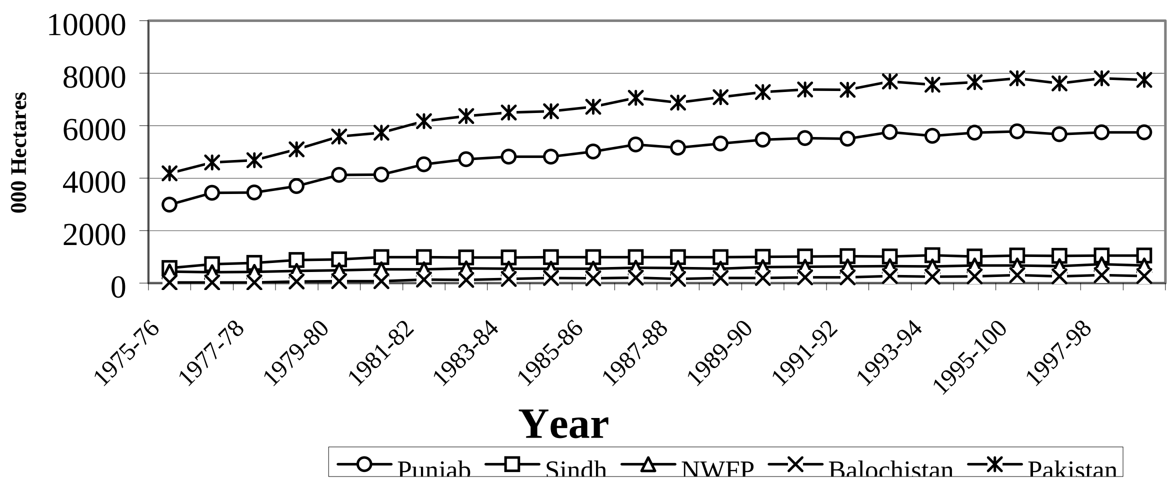

Figure 9. Distribution of area with respect to high yielding varieties of wheat in Pakistan.

Apart from the diffusion of improved seed varieties of wheat for better production, availability of improved wheat seed is of key importance for higher production. It is clear that the use of right amount of wheat seed for sowing cannot achieve the required objectives until and unless seed used bear the potential characteristics of healthy seed (size, maturity, free from diseases, etc). If seed used is not healthy, then, there are chances that farmers will have to use more seed per hectare. Figure 10 (Pakistan, 1986, 1994, 1996, 2000). showed the improved seed distribution from 1986-87 to 1998-99. It depicts that a wave of higher amount of improved seed supplied to farmers was felt in 1979-80 mainly in Punjab and lasted till 1993-94. During this period, quantity of improved seed distributed ranged between 40-60 thousand tonnes per annum. After that, the supply of improved seed increased dramatically up to about 105 thousand tonnes in 1998-99.

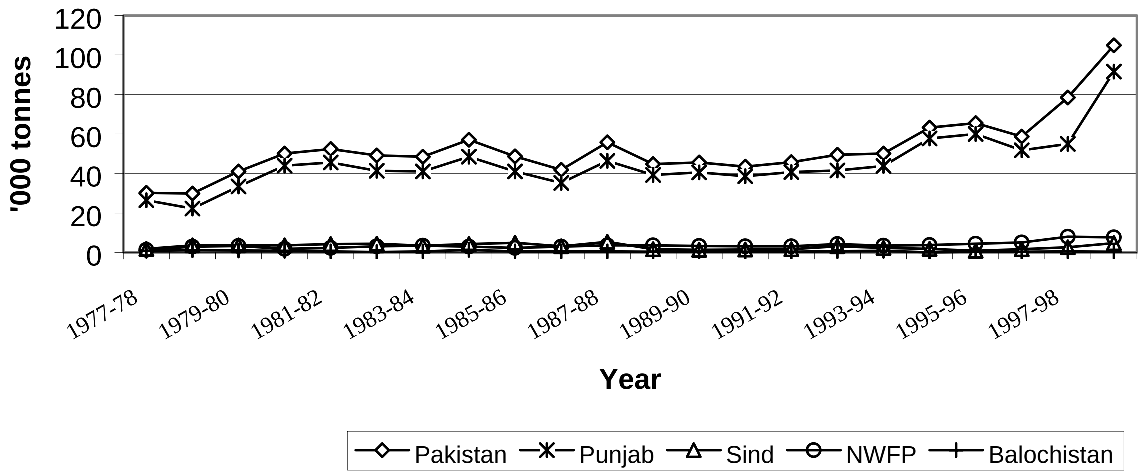

Figure 10. Distribution of improved wheat seed in Pakistan.

1.4 Fertilizer

Figure 11 (Pakistan, 1986, 1994, 1996, 2000) showed the fertilizer consumption pattern during rabi since 1975-76. It is evident that the behavior of total fertilizer consumption curve was dependent mainly on use of Nitrogenous fertilizer. Potash fertilizer was another main category. It is also interesting to note that overall use of fertilizer increased about seven-fold during the above-mentioned period. This higher usage of fertilizer clearly indicates a thrust for growing more crops per hectare of land because modern varieties express their full yield potential when soil fertility is high (Hobbs and Morris, 1996).

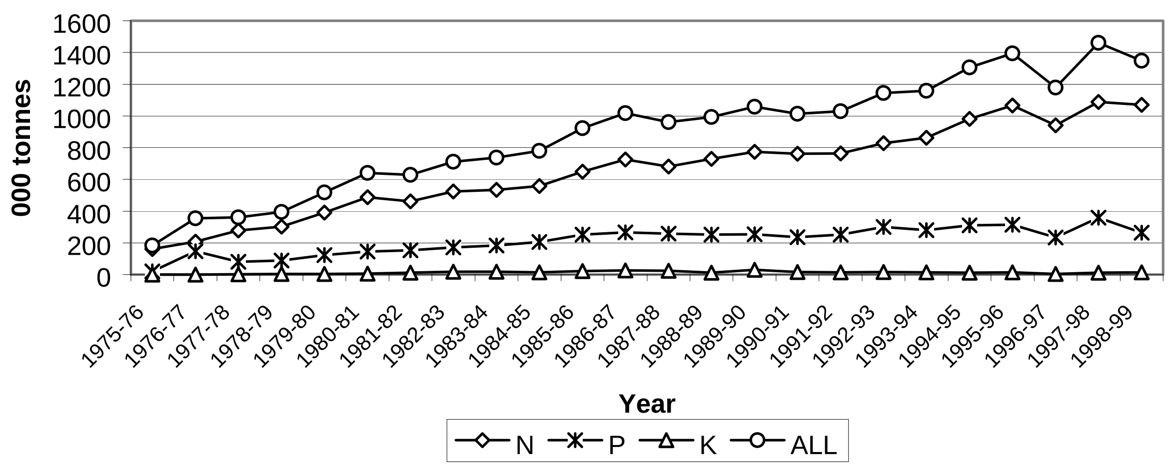

Figure 11. Different fertilizer and their consumption during rabi in Pakistan.

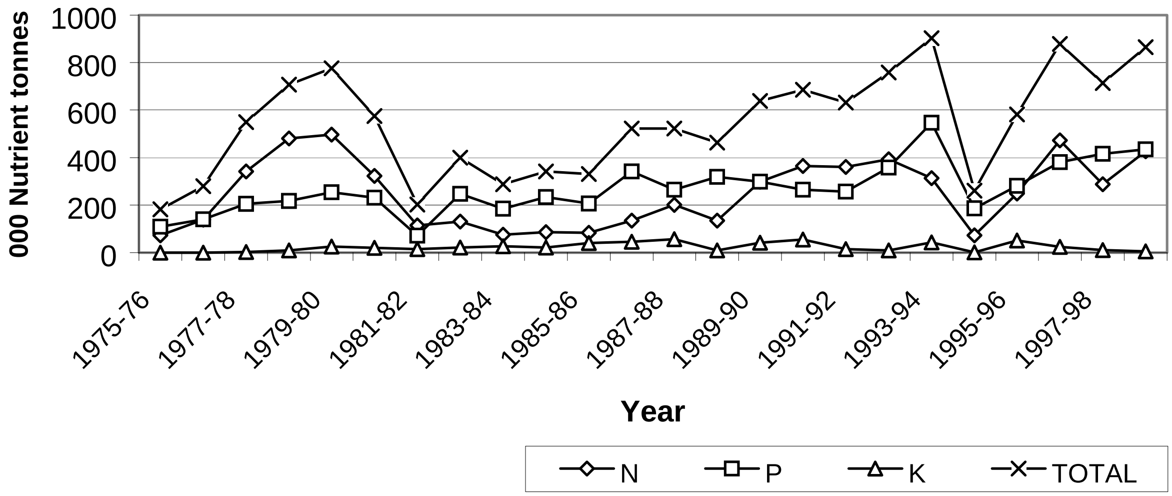

Figure 12. Different fertilizers and their import in Pakistan.

As the demand for fertilizer increased due to high pressure on limited productive resources for more output per unit of land, use of fertilizer increased over time. Unfortunately, inability of meeting the local demand by local production resulted in import of fertilizer. This history of fertilizer showed a continuous strain on national resources that were need for the import of fertilizers as depicted in Figure 12 (Pakistan, 1986, 1994, 1996, 2000).

On one side, more expenses were incurred on the import of fertilizer in order to meet higher fertilizer demand, while on other side farmers were unable to pay the international price of fertilizer for each unit of fertilizer used primarily due to poor economic condition. In this situation, the government came ahead and provided subsidy on fertilizer so that farmers may purchase inputs necessary for crop production. The Figure 13 (Pakistan, 1986, 1994, 1996, 2000) shows the amount of subsidies provided to farmers on fertilizer. In this regard, government for providing subsidy to farmers each year from 1977-78 to 1993-94, spent a significant amount of funds. From 1996-97 onward, government abolished the subsidy on fertilizer and farmers had to bear the full cost by themselves for fertilizer usage. It is also interesting to note that, in 1996, the fertilizer demand was also decreased, but afterwards it increased again.

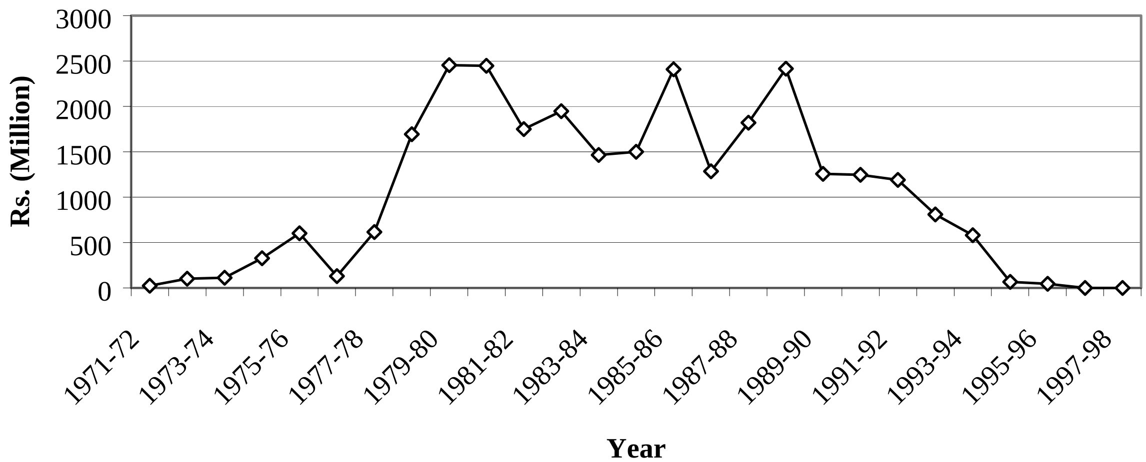

Figure 13. Subsidy provided on fertilizer in Pakistan.

1.5 Wheat Pricing

Investment in inputs for getting higher yield and production cannot go ahead without good produce price received by farmers. In order to save farmers from low produce price situation at the time of harvest for their crops, government has to tackle the situation through different tools. For wheat in Pakistan, this means pegging of a minimum price per 40 kg of wheat grains and in case market forces do not adjust themselves according to the proposed wheat prices government starts purchasing of the wheat at that minimum price from farmers. This purchased wheat is then, provided to the markets throughout the year and in this way, farmers are saved from exploitation in the hands of local market forces. Even now, considering the government's limited buying capacity, significant proportion of farmers had to face the above-mentioned embarrassing situation.

Figure 14 shows the history of setting up procurement/support price for wheat in Pakistan. In 1998-99, government did not peg the prices, but in the very next year, a new support prices was announced keeping in view of the possible exploitation of the farmers.

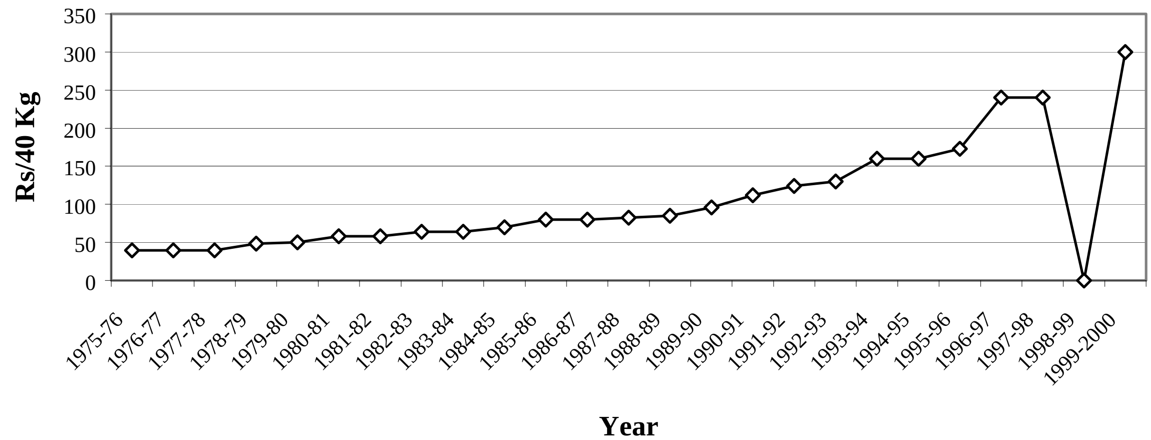

Figure 14. Procurement/support price of wheat in Pakistan.

1.6 Credit

Figure 15 presents the annals of supply of agricultural credit disbursed to farmers for agricultural purposes. The provision of the agricultural credit was mainly to increase the purchasing power of the farming community for buying different agricultural equipments and other inputs needed for the production of crops. Since 1980-81, the amount supplied to farmers has been increased more than seven times till 1998-99. The record also shows two long periods when credit supply remained stagnant for many years while a very steep line (high supply) in the last two years was also recorded.

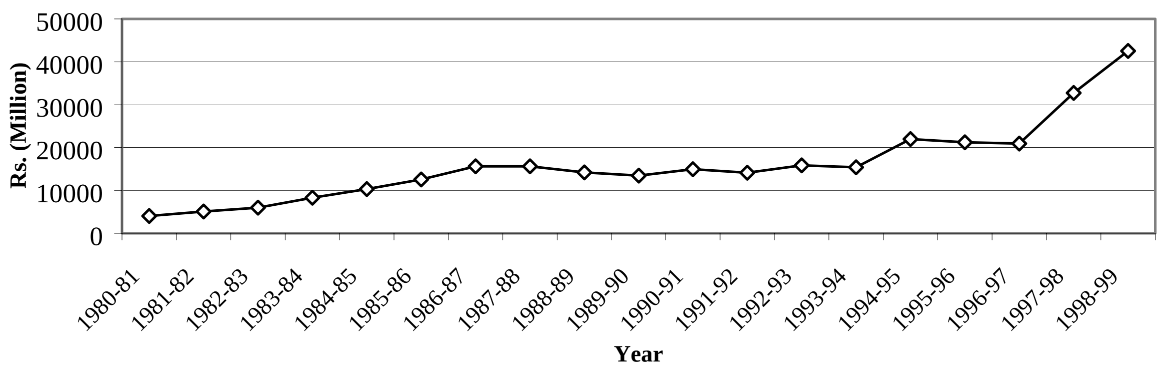

Figure 15. Supply of agricultural credit by formal institutions in Pakistan.

2. INPUT REQUIREMENTS FOR WHEAT

2.1 Land Preparation, Sowing Timings, and Techniques

Good land preparation and timely sowing of the wheat seeds are inevitable for reaping a potential harvest. A properly ploughed and leveled land is necessary for better future harvest. As for the germination of seed, proper climatic conditions are needed so sowing time becomes more sensitive in this regard.

Aslam (1998) reported that basin irrigation is used for irrigation application for wheat crop. Size of the basin varied considerably and it was bigger where public tubewell water was applied. This led to wide range of application efficiencies and distribution uniformity.

Punjab (2000) suggested that proper land preparation before sowing was very important for a good wheat harvest. It also recommended that land should be divided into small plots so that better ploughing and leveling be done that would also benefit by destruction of weed plants already present in the field. This would also enable the farmers to irrigate land with less water application. The number of ploughing and planking differed with characteristics of soil and availability of irrigation water for 'Rauni' irrigation (pre-irrigation).

Pintus (1997) described that according to local institutions, best sowing time was November for wheat crop. However, majority did not follow the rule due to variety of reasons such as sowing after rice, sugarcane, or fodder. Some also attributed low cash and thus, delayed renting of the tractor and fertilizer. Only eight percent of the farmers sowed wheat before November 30. She found that majority of the farmers' sowed wheat from 30 November to 31 December.

Sowing of seed was done through Rabi drill and broadcast method while later was more prevalent in the area. Majority of the farmers practiced broadcast method for wheat sowing where as progressive farmers were using Rabi Drill for sowing the wheat crop (Aslam, 1998). About 9 percent of farmers in Irrigated Punjab employed broadcast method for sowing while rabi drill or kera method separately or in combination with broadcast method was used by about 9 percent of the farmers (Azeem et al, 1991).

Azeem et al. (1991) found that about 31 percent of the farmers sowed wheat before November 15 where as by December 15, about 59 percent of the farmers had completed sowing in irrigated areas of Punjab. It was also found that only 12.5 percent of the farmers did not complete wheat sowing by December 30.

Table 1. Distribution of planting dates of wheat crop in irrigated Punjab.

Planting Dates	Irrigated Punjab (%)
Up to November 15	31.4
November 15- December 15	27.3
December 15 – December 30	28.8
After December 30	12.5

(Source: Azeem et al., 1991).

2.2 Fertilizer

Conservation and replenishment of the fertility of land is the need of the time to cop with the increase in the total demand for food grains primarily due to consistent rise in population. The increasing burden on agricultural land for getting more produces in order to feed the masses, demand the use of fertilizer (organic and inorganic) in suitable quantities for replenishing its fertility.

Punjab (2000) gave recommendation for type and amount of fertilizer based on the fertility of the soil for wheat production. Nitrogen, Phosphorus, and Potash are the main ingredients needed to uplift the soil fertility. Different types of fertilizer are available in the market to fulfill the needs for these ingredients i.e., Urea, Single super phosphate, Di ammonium Phosphate, etc.

Table 2 shows combination of different fertilizers needed for land of different fertility level and for different crop stages. Usually, at the time of sowing, application of DAP, Urea, and Potassium Sulphate was recommended while afterward only urea application was recommended with first or second irrigation.

Table 2. Recommended dosages of fertilizer based on fertility of land and crop stage.

Land fertility	Fertilizer dosage at sowing time	Fertilizer dosage with first or second irrigation
Low	DAP = 2 bags Urea = 0.5 bag Potassium Sulphate = 1 bag	Urea = 1 bag[4]
Medium	DAP = 1.5 bags Urea = 0.5 bag Potassium Sulphate =1 bag	Urea = 0.75 bag
High	DAP = 1 bag Urea = 0.5 bag Potassium Sulphate = 1 bag	Urea = 0.5 bag

(Source: Punjab, 2000).

2.3 Varieties and Seed

Good variety and seed quality along with proper seed quantity used are of prime importance for boosting the wheat production. Despite so many difficulties in evolving a good wheat variety, government is trying a lot to increase the area under improved varieties in all over the Pakistan. A number of varieties are introduced in last decade that are suitable for various agro-climatic regions as well as for early and late sowing.

Table 3 provides a list of recommended varieties for irrigated and barani areas of Punjab. The listing of the recommended varieties is not complete because it refers to recommended varieties for Punjab only, yet it reflects the effort of agriculture department for diffusion of improved

[4] One bag contains 50 Kg of Fertilizer

varieties in all over the Pakistan. It also tells that the breeders are well aware of the need evolving varieties with respect to the specific characteristics of the area.

Table 3. Recommended wheat varieties based on sowing time and area.

For Barani Areas		
Variety	Time of Sowing	Recommended Areas
Chakwal-86	October 20 to November 15	All barani areas of Punjab
Rawal-87	October 20 to November 15	All barani areas of Punjab
Kohsar-95	October 20 to November 15	All barani areas of Punjab
Kohistan-97	October 20 to November 15	All barani areas of Punjab
Chakwal-97	October 20 to November 15	All barani areas of Punjab
Inqulab-91	November 1 to December 10	All barani areas of Punjab with more rain and partial access irrigation
Faisalabad-85	November 20 to December 10	All barani areas of Punjab
For Irrigated Areas		
MH-97	October 25 to November 30	Central and southern areas of Punjab (for early sowing)
Uqaab-2000	November 1 to December 15	Central and southern Punjab
Punjab-96	November 1 to November 30	All Punjab
Pasbaan-90	November 1 to November 30	Central and southern Punjab (in saline soils for early sowing)
Inqulab-91	November 10 to December 15	All Punjab
Bahawalpur-97	November 15 to December 15	All Punjab
Iqbaal-2000	November 15 to December 15	All Punjab
Bahawalpur-2000	November 25 to December 15	Southern Punjab
Parwaz-94	November 25 to December 31	All Punjab
Faisalabad-85	November 20 to December 15	All Punjab

(Source: Punjab, 2000).

Punjab (2000) also discussed that after November 20, delay in sowing of wheat crop resulted in 37-50 kg less production on per hectare basis. It was also suggested that for irrigated areas of the Punjab, different seed quantity should be used according to the time of sowing.

The recommended quantities for sowing till November 15, November 16-30, and December 1 to onward were about 125 to 175 kilogram per hectare if seed germination percentage was no less than 90 percent. Otherwise, a suitable increase in quantity of seed applied per hectare was recommended for better production.

Aslam (1998) discussed that majority of the farmers apply less seed per unit of land as compared to recommended seed quantity for wheat crop (125 kg/ha). The poor quality seed resulted in the lower plant population that in turn resulted in low yield of the wheat crop.

2.4 Irrigation Water

As being the key input in crop production, the application of irrigation water in appropriate quantity and at proper time (according to the requirements of crop) is necessary for getting potential yield. Delay in irrigation especially at critical stages of growth (tillering, booting, flowering) can cause potential losses in yield and excessive irrigation can cause water logging and salinity problems in the long run.

Punjab (2000) advised that first irrigation should be applied within 20-25 days if wheat is sown after cotton, maize, or sugarcane where as recommended duration increased up to 30-40 days if sown after rice. In total 3-5 irrigations were considered enough from sowing till harvest of the crop depending upon the climatic fluctuations and groundwater Table depths in the area.

Aslam (1998) elaborated that wheat yield increased with the number of irrigations applied. He found that farmers who irrigated the wheat fields for less than four times obtained wheat yield equal to 765 kg/ha. On the other hand 4-7 irrigation applications to the field yielded 1410kg/ha of wheat. Additionally, if irrigation applications were more than 8 then, wheat yield was estimated as 1641 kg/ha. He also noticed that farms near the source of irrigation water were getting higher yield as compared with the farmers that were located in the middle or tail reach. The effect of farm location on the wheat yield is elaborated in Table 4.

Table 4. Effect of Farm Location on the Wheat Yield

Farm Location	Yield (Kg/ha)
Head	2249
Middle	1779
Tail	2009

(Source: Aslam, 1998).

Pintus (1997) found that there was no set rule prevalent within the farming community regarding the number of irrigations needed from sowing till maturity of wheat crop. Mostly, it depended upon farmer’s own perception. Some farmers applied water to the field on the basis of plant’s appearance while others applied after every thirty days not considering the crop requirement. It was also found that majority of the farmers irrigated their fields five to six times in the season. However, the number of irrigations ranged from 2-8. It was also found that number of irrigations increased with the availability of the tubewell water. It was also found that the average quantity of irrigation water including pre-irrigation was 450 mm. Interestingly, it was found that although the total amount of water has no link with the date of sowing, number of irrigations tended to increase with delayed sowing.

2.5 Pesticides, Weedicides, and Herbicides

Different weedicides and herbicides are available for controlling the un-wanted plants growing in the wheat fields.

Punjab (2000) devised different methods to control the weed growth in the wheat fields. The primary methods were by land preparation, crop rotation, inter-culture, and increase in seed quantity used for sowing on per acre basis. However, the weedicides and herbicides usage was recommended if above-mentioned methods were found insufficient for controlling the weed population in the wheat fields. The use of chemicals was mainly advised soon after sowing or after first irrigation. The type of chemicals and quantities differed on the basis of weeds that needed to be controlled.

2.6 Water Management Practices

Punjab (2000) recommended proper land leveling and division of land into small plots for decreasing the amount of irrigation water needed for irrigating more land in an efficient manner. Before sowing, a ploughing after every rainfall was also recommended in order to conserve the water in the land.

Rawson and Macpherson (2000) opined that irrigating the wheat crop according to regional recommended intervals saves the crop from moisture stress problem. Moisture stress in early stages leads to poor leaves, tillers, and spike formation and consequently thin canopy, few small pikes and few grain with low yield is the outcome. In order to avoid moisture stress better water management is needed taking into account of evapotranspiration (Table 5 and 6).

Table 5. Evapotranspiration values for different environments (mm/day)

	Average Daily Temperature (^oC)		
Evaporation (mm) per day	10-16	17-23	24-30
Humid tropics	3-4	4-5	5-6
Subhumid tropics	3-5	5-6	7-8
Semiarid tropics	4-5	6-7	8-9
Arid tropics	4-5	7-8	9-10

(Source: Rawson and Macpherson, 2000).

Table 6. Evapotranspiration crop coefficient for crops reaching 80-90 percent full ground cover by heading

Growth Stage	Crop Coefficient	Crop Ground Cover
Early vegetative growth	0.3	10-30 %
Tillering	0.8	30-80 %
Stem Elongation to Flowering	1.0	70-100 %
Grain Filling	0.5	20-50 %

(Source: Rawson and Macpherson, 2000).

3. CONSTRAINTS TO WHEAT PRODUCTIVITY

3.1 Environmental constraints

3.1.1 Waterlogging

"Report of the National Commission on Agriculture, 1988" disclosed that since independence (1947), water logging and salinity problems were present. Traditionally, these two land evils occur together. The report also recognized that fertilizer and input use efficiency was greatly reduced on the salt-affected soils resulting into decline in yield and production. Additionally, due to different public measures, it was generally agreed that saline and waterlogged areas that were of significance to agriculture were not as large as had been suggested. The use of gypsum was recommended while areas with high sweet water Table could be drained through the effective use of private tubewells.

Aslam (1998) identified water logging as a major constraint refraining farmers for achieving increased productivity. It was stated that wheat yield could reach to potential threshold only when water Table should be below than 1.5 meter depth. If water Table was above the 1.5 meter depth, wheat yield started to be affected. Significant decrease in wheat yield was estimated when water Table was within one-meter depth. Table 8 showed the relationship between water Table depth and percentage yield reduction caused by it.

Table 8. Effect of different water Table depths on wheat yields.

Water Table Depth (cm.)	Percent Yield Reduction
0-5	79
25-50	49
50-75	28
75-100	13
100-125	5
125-150	1
150-175	0

(Source: Aslam, 1998).

Rawson and Macpherson (2000) discuss that wheat deteriorate rapidly in waterlogged soils if temperatures are high. Seedlings die within as little as two days. Later stages are more tolerant but can still lose a high proportion of their leaves and thus yield. Wheat crop growing in mildly saline soils will not be able to survive if waterlogging occurs.

3.1.2 Soil Salinity

Pintus (1997) based on the review of literature described the effect of salinity on wheat crop at different crop stages (Table 7). It was discussed that salinity affected the wheat plant growth at germination and tillering stages, especially at later stage. It affected the wheat through weak root development and shoot growth. It would also be interesting to note that salinity effects crop during early days of plant growth.

Table 7. Crop stages of wheat and sensitivity to water and salinity hazards.

Stages	Number of Days	Events	Hazards	Effects
Germination	7-10	From sowing to first leaf	Salinity +[5] Soil crust	Weak root development Low germination rate
Tillering-crown root initiation	15-20	From first leaf to third leaf	Salinity +++ Water stress +++	Weak roots and shoots growth
Jointing	30-35	1 cm long spike and end of tillering		Lower density
Booting/heading	15-20	From plant growing up to fecundation	Water stress +++	Spikes abortion
Flowering	10-15	From flower apparition to grain growth	Water stress +++	Flower fading
Grain filling	15-20	Soft juicy grain	High temperature effect	Grains abortion
Dough ripe	10-15	Tough grain		
Total	102-135	harvest		

(Source: Pintus, 1997).

Rawson and Macpherson (2000) discussed that wheat grows best between pH 5.5 and 7.5 though it can be grown beyond this range with additives to the soil. It was elaborated that too high or too low pH results in excessive availability of certain nutrients that is toxic to the crop while others are less available than required. It was also asserted that salinity could cause problem only when certain salts concentrate in the crop's rooting zone. Salinity resulted in reduced growth due to poor expansion of leaves and tillers leading to low yield. Sodicity led soil physically unstable, crumbling and cracking when dry while collapsing when wet. Use of agricultural lime, application of organic manure, averting the use of fertilizer, use of gypsum, and improvement of drainage were advised to overcome the soil acidity or alkalinity problem. Use of salt tolerant varieties of wheat, heavy infrequent irrigations, deep cultivation, use of organic matter, use of mulches to decrease evaporation were advised to avoid the serious problems in the growth of wheat crop for better yield.

Siddiq (1994) found that farmers were aware of the soil salinity problem but due to poor quality of ground water, their efforts were proven unsuccessful in order to decrease the salinity problem in their farmlands. He also estimated a yield loss of 231 kg/ha to 411 kg/ha due to soil sodicity. The tail reach farmers were affected most due to sodicity problem as compared with the head and middle reach of the distributaries.

[5] + to +++ sign shows growing importance of hazard

3.1.3 Irrigation Water Supplies

Aslam (1998) elaborated that the water requirements for wheat ranged from 450-650 mm, depending upon the climate and length of the growing season. However, actual observed amount of water applied to wheat varied from 200-750 mm including all irrigations and rainfall during 1987-88 as reported by Bhatti et al. (1989). It was further asserted that in Punjab Province, farmers deliberately over-plant and under-irrigate wheat with a hope for winter rainfall that would provide the deficit needed. Under this situation, if it rained then farmers got high yield otherwise low yield was evident.

3.1.3.1 Warabandi

Memon et al. (1997) discussed that there were two arrangements for water distribution at watercourse level; Pakka Warabandi (officially fixed by the Provincial Irrigation Department), and kachcha Warabandi (managed by farmers with mutual agreement). The pakka Warabandi was officially notified and farmers had to follow that.

Through pakka Warabandi, water was distributed among all the shareholders of a particular watercourse based on the area under command. As the outlet discharge was fixed, the farmer with more land was provided with more time, which was utilized for irrigating the field.

In addition to Kachcha and Pakka Warabandi systems, exchange of water turn/swap waras also took place. Terpstra(1998) elaborated the exchanging of canal water turns as a strategy to acquire more water, although it was found temporary arrangement in nature. It was also asserted that most of the times this happened among farmers having farms in close proximity. It was also found that the farmers having land in more parcels were the main beneficiaries with exchange of water turns.

3.1.3.2 *Tubewell Irrigation*

Aslam (1998) opined that the adequate availability of water for irrigation was mainly dependent on the tubewell water in the Punjab, Province. The input use in proper quantities was also found dependent on the adequate water availability especially in terms of fertilizer usage. Table 9 supported this idea with reference to wheat yield in wheat-rice zone of the Punjab province. It clearly depicted that with adequate availability of irrigation water farmers tended to irrigate their fields more frequently. This higher frequency of irrigation was accompanied with higher use of fertilizer and ultimately, resulted in higher wheat yield.

Table 9. Wheat yields according to the adequacy of irrigation turns.

Location	**No. of Farmers**	**Average no. of irrigation turns**	**Percent us**		**Average Yield (Kg/ha)**
			N	P	
Adequate Water	18	7.1	100	72	1521
Inadequate Water	73	5.6	82	38	1260

(Source: Aslam, 1998).

3.1.3.3 Conjunctive water use

Unavailability of cheaper canal water and access to costly tubewell water led most of the farmers towards conjunctive water management.

Aslam (1998) found that fields with access to a combination of canal and private tubewell water performed better in terms of efficiency of water use (316 mm average seasonal water applied) and productivity for yield per unit of water applied (0.94kg/cu.m). Fields with conjunctive water use, canal water use, and tubewell water use are ranked accordingly on the basis of their water use performance. Practically, irrigation per turn for wheat may vary from 51 to 254 mm. He found that irrigation supplies from public sources were used with considerably lower efficiency than private ones.

3.1.3.4 Timely availability

Pintus (1997) reported that the timely irrigation application to the wheat field was of much importance. The wheat crop was found very sensitive towards water stress during tillering, booting, and flowering stages that could lead to poor harvest due to weak roots and shoots growth, spike abortion, and flower fading, respectively.

Aslam (1998) discussed that the water shortage appeared to be acute during late rabi. A comparison of water availability during rabi showed that unavailability of the irrigation water at the critical stages affected the yield most. Table 10 showed the extent of loss of yield due to unavailability of irrigation water in November (tillering stage of wheat crop) and February (anthesis stage). The highest yield loss was found when the water shortage occurred at both critical stages of the wheat crop.

Table 10. Effect of water shortages on wheat yield.

Water Shortage Months		% of cases	Average Yield
November	February		
Yes	No	9	2855
Yes	Yes	36	2585
No	No	55	2977

(Source: Aslam, 1998).

Jehangir and Ali (1997) while using the Cobb-Douglas model identified the canal irrigations as one of the main source of variation in wheat yield in Rechna Doab, Punjab area. They found that due to less water availability at the time of application, the usage of fertilizer and weedicides was low.

3.1.4 Drainage Problems

Aslam (1998) asserted that inadequate drainage is also a major constraint towards achieving the potential yield for wheat. Irrigation excess and rainfall run could be wiped out from the area through evaporation and deep percolation. Use of surface drainage might lead to removal of water from the soil surface that could lead to drying up of surface soil without reduction in water available at the crop roots. As the water Table was needed to be 1.5 meter below the surface in order to save wheat crop from potential yield loss, it required a good water Table control for higher yield. Moreover, removal of water from surface only could initiate a higher salt concentration towards soil surface through capillary action. It was also opined that for proper land preparation for wheat, drainage of excessive water was necessary in kharif season to avoid poor and delayed land preparation. Poor and insufficiently proper drainage could lead to twin problems of water logging and salinity in the area. Though Salinity Control and Reclamation Projects (SCARP) had played an important role in decreasing area under waterlogged condition, salinity was still a main problem in the areas. it was therefore suggested that farmers should be educated for employing chemicals like gypsum and biological techniques for reclaiming the salt-affected lands along with using the drainage measures for lowering the water Tables.

3.1.5 Climatic Factors

Aslam et al. (1989) made use of on-farm research experiments data in order to find out the constraint to wheat productivity in rice-wheat zone of the Punjab. They found that in addition to a good irrigation canal system, rainfall in rabi was an important factor contributing to wheat production though intensities varied year to year. Another important factor was temperature. The wheat production was affected by high temperatures at flowering and early grain filling stage (in late March and April). It was also found that the climatic factors had more effect on late sown wheat.

Rawson and Macpherson (2000) discussed that emerging seedlings could be rapidly desiccated if soil temperatures reached 40 degree Celsius or greater. High temperatures at flowering and grain filling stages might shorten the season and reduce yield. Light irrigations (especially sprinkler irrigation), selection of optimum sowing time, selection of suitable variety, and use of mulch might be helpful in overcoming this problem.

3.2 Agronomic Constraints

"Report of National Commission on Agriculture, (1988)" recognized the past achievements of substantial increases in wheat yields were due to high yielding varieties and a balanced used of inputs, especially seed, water, and fertilizer. It also suggested evolution of rust resistant varieties with respect to different agro-ecological zones along with adoption of improved agronomic practices for future success.

3.2.1 Land Leveling

Aslam et al. (1989) found that if little time was available for cultivation of land before sowing of wheat then zero tillage was a likely solution averting the delay in wheat sowing. Based on different field experiments during 1984-88, they compared yield obtained by employing zero tillage technique and widely practiced farmers' techniques. The estimates given were provided in Table 11 showing that zero tillage was a powerful way of cutting down the land preparation and costs incurred with out any loss in yield per hectare. The only probable criticism was that yield gained was from experimental farms and there was a need to establish the real gain/loss when used by common farmers.

Table 11. Yield differentials with respect to zero tillage and prevalent farmer practices for land preparation.

		Grain Yield (Kg/Ha)		
Year	No. of Locations	Zero Tillage	Farmers' Practice	Significance
1984-85	8	3032	3257	5%
1985-86	15	3600	3516	Not Significant
1986-87	13	3791	3509	2%
1987-88	6	4279	3560	1%
Average	-	3675	3465	

(Source: Aslam et al., 1989).

Rawson and Macpherson (2000) opined that land preparation should be done with an aim to create soil structure that encourages the rapid and uniform emergence of seedling and allow the plants ready access to the vital resources of nutrients, water, and aeration. Most importantly, it should be shaped in such a fashion so that irrigation water could be applied efficiently and drained effectively so that waterlogging is avoided or minimized. If little time or lacks of equipment are the problems then it may not be possible to have good preparation of land especially if farming system uses flood or furrow irrigation.

3.2.2 Seed and Variety

Farmers use different sources of wheat seed that include home seed, other farmers, dealers, and seed corporation. Though major source is home seed, choice of source depends upon many other factors.

Akhtar et al. (1986) did wheat varietal verification in the irrigated Punjab, Pakistan. They found that two-thirds of the farmers grew single wheat variety in their field where as about 50 percent of the large farmers (>10 hectares) grew two or more varieties in their field. Additionally, about 75 percent of the farmers were growing old or banned varieties of wheat as told by farmers. However, a team of qualified breeders found that the situation was even worse in Rice-wheat zone. The main factors identified were farmers' knowledge, availability of seed, and credit.

Ali and Iqbal (1984) found that modern wheat varieties were contributing more to improve the wheat yield in Punjab than old varieties. Moreover, the modern varieties were found beneficial for both irrigated and barani areas.

Altaf (1994) disclosed that Pakistani farmers were facing low germination percentage and low seedling vigor problems from the seed used by the farmers. It was also spotlighted that only 6 percent of the wheat seed used by the farmers was certified. The policy recommendation was that at least 20 percent of the seed used by the farmers must be certified in case of wheat.

Heisy et al. (1987) based on a survey meant for monitoring wheat varieties grown in three major cropping systems of Pakistan, discussed that a large number of farmers were growing banned varieties of wheat. This finding was based on the perception of farmer about the wheat variety, he was growing in his field. The situation is worst in case of areas marked with maize/sugarcane-wheat rotation where as it is comparatively better in Rice-wheat zone. Moreover, about forty percent of the area was discovered under banned varieties of the wheat. The share of newly recommended wheat varieties was estimated about one-fifth to one-fourth of the total area under wheat crop. Interestingly, they found discrepancies in the farmers' perception about wheat variety grown in the field and experienced breeders' recognition of the wheat variety grown in the field. In this regard, main dissimilarities were found in maize/sugarcane-wheat zone. The study concluded that for proper identification of all wheat varieties, a very experienced breeder with thorough knowledge was a requirement. Otherwise, results would be based completely on the farmers' perception and knowledge that showed divergence from the actual situation.

Khusk et al. (1989) conducted research for finding out the wheat varietal diffusion in cotton and rice zones of Sind. They found that though majority of farmers were growing a single variety of wheat in their fields however, about 40 percent of the farmers cultivated two or more varieties of wheat in their field. Another major finding was that about 30 percent of the farmers were growing banned varieties of wheat in their field. It was also found that large farmers tended to have more area under new recommended varieties of wheat where as the case was reverse for the small farmers.

Tables 10 showed a variety of sources available for wheat seed. However, about two-third of the farmers were using their own seed for sowing the wheat crop. It was also found that seed from other wheat farmers was the second most important source of seed. However, it was clearly a point of disappointment that only about 7 percent of the farmers used seed that was obtained from seed depots or research and extension department.

Table 12. Farmers' seed sources for wheat varieties planted in Sindh.

Seed Source	Cotton Zone (%)	Rice Zone (%)	Average (%)
Own	58	65	61.5
Landlord	15	9	12
Other Farmer	12	13	12.5
Seed Depot	5	3	4
Village Shop	7	8	7.5
Research/Extension	3	2	2.5
Total	100	100	100

(Source: Khushk et al., 1989).

Ahmad et al (1989) studied the diffusion of wheat varieties in the irrigated areas of Baluchistan and found that over all 39 percent of the cultivated area was under wheat crop. Moreover, 41 percent of the average cultivated area was under the recommended varieties of wheat. In this respect, it is interesting to note that tenants put more area under wheat cultivation than owner cultivators. Additionally, small and medium farmers were growing more area under single wheat variety as compared with the large farmers in their field. It was also worth noting that areas under recommended wheat varieties were found closed to Sind that was the main market for their output.

3.2.3 Sowing

Altaf (1994) discussed that each day's delay in sowing of wheat after mid November resulted in a 1 percent loss in yield because of enforced wheat flowering and temperature stress during grain filling in March and April. Therefore, sowing should be done at proper timing so that yield loss could be minimized.

Rehman (1986) pondered that wheat sown in October or November bore high yield as compared with January sowing. For high yield, it was asserted that sowing must be completed before November 30. It was also opined that there was no significant change in potential yield of wheat when sown in December or January.

3.2.4 Fertilizer

Ali et al. (1984) conducted a study to find out the constraints to high yield of wheat in Punjab through field experiments along with survey data for socio-economic variables. They found that fertilizer use was less than recommended levels in both irrigated and barani areas of the Punjab. It was also estimated that about 25 percent of the farmers were using near to recommended dosages of the fertilizer. It was also found that all the farms in barani areas applied fertilizer where as in irrigated areas 99 percent of the farmers used fertilizer, but 1 percent applied farmyard manure for improving the fertility of the soil. Table 13 showed a slightly high level of fertilizer application in irrigated areas as compared with the barani areas.

Table 13. Fertilizer use (bags/acre) on sample farms.

Fertilizer	Barani Areas	Irrigated Areas
Urea	0.89	1.11
DAP (Di Ammonium Phosphate)	0.97	1.02
NP (Nitro-Phos)	1.03	1.5
SSP (Single Super Phosphate)	-	2.08

(Source: Ali et al., 1984).

3.2.5 Chemicals

The use of chemicals in case of wheat crop is meant for seed treatment before sowing, for controlling diseases and weeds.

Ahmad et al. (1988) while establishing the fact that weed management was lowering the wheat yield argued that herbicides usage should not be tried to promote where it is uneconomical. They also suggested that extension services and on farm demonstration should be employed in order to disseminate knowledge about herbicides.

3.2.6 Weeds

Ahmad et al. (1988) found that farmers perceived high weed growth as a problem with a potential to decrease the yield up to 0.4 tons/hectare. They also found that use of bar harrow for eradicating weeds was very much limited while rauni method was also not very much practiced because of expected delay in sowing of wheat crop. It was also discovered that despite surplus labor and time for timely sowing of rabi and kharif crops, herbicides usage was mostly confined to large farms. They also suggested that more weed management alternatives should be experimented for effective weed management. The dummy for farm size regarding use of herbicides for controlling weed in Probit analysis was significant and negative showing that large farmers may actually be less likely to be aware of herbicides.

Ali et al. (1984) estimated that appropriate weeding contributed about 18 percent in irrigated areas and 16 percent in barani areas to wheat yield. Interestingly, it was also found that only about 23 percent of the farmers were practicing weeding once or twice in a season in irrigated areas. Use of weed as a fodder in barani areas was the most prominent reason for not weeding the wheat fields. On the other hand, in irrigated areas higher labor cost as well as farmers' perception and knowledge on effects of weed on wheat yield contributed more.

Table 14. Reasons for not weeding wheat field.

Area	Barani Areas (%)	Irrigated Areas (%)
Higher Labor Cost	25	30
Use Weeds as Fodder	54	21
Weeding not essential for high yield	11	30

(Source: Ali et al., 1984).

Rawson and Macpherson (2000) argued that weeds compete with wheat crop for light, nutrients, water, and root space. Some weeds produce toxic substances that harm the wheat crop. Annual weed compete with wheat crop during seedling and early tillering stage so this is the critical period for weed control. It is opined that once crop is covering 50-70 percent of the soil surface at jointing, it becomes able to dominate most newly germinating weeds. During harvesting, weed seeds can contaminate the grains.

3.2.7 Irrigation Water

Bhatti et al. (1988) found that late irrigation caused more tillers to grow to maturity and to produce heads even though the number of tillers should have set before the March irrigation. They also found that correlation between yield and growing season water was insignificant, indicating that the absolute amount of water applied in a season did not affect wheat yield. However, the authors opined that distribution of water in the season might be an important factor in maximization of wheat yield.

Table 15 showed that the yield was negatively correlated with wheat yield indicating that late sowing after November resulted in loss of yield. However, a positive correlation between yield and Rabi rainfall was estimated showing a positive contribution towards increase in wheat yield. This also implied that wheat water requirements were not fully met and farmers had planted more wheat than they can expect to irrigate effectively. In addition to this, they also projected that a late irrigation treatment increased yield by 210 kg/hectare. They suggested that farmers should not be reluctant in applying an additional irrigation late in the season. The main implication of the research was that as long as the wheat crop was well watered in March/April, it could recover easily from earlier period of stress. Despite the variation in farmers' practices, a late irrigation at soft dough stage increased yield by 6 percent and it was expected that in normal years, rise in yield would be even more than this. Moreover, adequate march irrigation was considered critical for wheat crop.

Table 15. Correlation coefficients for factor that did not vary with irrigation treatment (1987-88).

Factors Measured		Correlation Coefficient	Significance Probability
Yield vs.	Sowing Date	-0.212	1 %
	Days to Harvest	0.099	5%
	Rabi Rain	0.123	1%
	March Rain	0.046	Not Significant
Water vs.	Sowing Date	-0.114	5%
	Days to Harvest	0.134	1%
Tillers vs.	Sowing Date	-0.048	Not Significant
	Days to Harvest	-0.023	Not Significant
	Rabi Rainfall	0.017	Not Significant
	March Rainfall	0.066	Not Significant

(Source: Bhatti et al., 1988).

3.2.8 Crop Rotation

Ahmad et al. (1988) noticed crop rotation as the most effective method for controlling the weed production. It was also observed that sowing of Berseem showed a negative effect on weed production. They also found that wheat cultivation on the same field for last three or more seasons resulted in high weed production.

Abrol et al. (1997) described that due to higher cost of Nitrogenous fertilizer, the need to improve the inorganic contents of the soil had become imperative. It was opined that inclusion of green manuring crop in the crop rotation would be considered as healthy practice. This would not only improve the soil fertility, but would also improve the soil properties, decrease pest incidence, etc.

3.3 Economic Constraints

3.3.1 Output Prices

Ali (1988) found that farmers are responsive to output and fertilizer price changes and they adjust their resources for the crops that experienced a price change as well as other crops that might be grown there. He estimated that price elasticity of wheat is low. According to his estimates, 10 percent change in output price will induce 3.6 percent change in production. He also found that wheat price did not affect the production of any other crops in a competitive way where as rice production had a complementary relationship with wheat prices. He concluded that food crops had relatively low own-price elasticities as well as had minor affect on the production of other crops. Technology was unleashed as a major non-price contributing factor towards crop production that led to 5 percent increase in wheat production during 1975-86.

3.3.2 Fertilizer Prices

Ali (1988) discovered that farmers were responsive to fertilizer price changes and adjusted the crop raising behavior accordingly. He discussed that although fertilizer price was a significant determinant of the crop production yet the long run fertilizer price elasticities of supply were found low in case of wheat.

Ali and Iqbal (1984) found that fertilizer use was one of the main factors affecting the wheat yield in Punjab province. They estimated that about 52-72 percent of the change in yield could be attributed towards fertilizer use. Additionally, economic evaluation of fertilizer showed that it has a higher benefit-cost ratio in irrigated areas as compared with the barani areas. On the other hand, they discovered that about 90 percent of the farmers in all provinces of Pakistan were unable to use fertilizer in recommended dosages. High fertilizer prices reduced the returns from fertilizer due to unfavorable input-output price relationship. Therefore, farmers tried risk aversion policies by not allocating more financial resources for fertilizer especially in barani areas.

Ali et al. (1984) analyzed the reasons for lower usage of the fertilizer and found that about 58 percent of the farmers did so due to higher prices of the fertilizer. Moreover, mainly farmers in barani areas than in irrigated areas perceived the use of fertilizer in higher dosage risky. On the other hand, water shortage was also a considerable factor attributing to lower usage on fertilizer than recommended. This is more evident in case of irrigated areas as compared with barani areas (Table 16).

Table 16. Reasons for lower use of fertilize (figures in percent).

Area	High Prices of Fertilizer	Water Shortage	Higher Use Risky
Barani	52	10	17
Irrigated	58	19	8

(Source: Ali et al., 1984).

3.3.3 Irrigation Water Charges

Chaudhry (1988) proposed uniform water charge policy for each province. He estimated water charges needed to defer operation and maintenance costs of the system for Punjab and Sindh Provinces with respect to different crops. He also estimated these regarding SCARP and NON-SCARP regions. According to the analysis, current water charges were lower in both provinces to defer the cost of provision of that water for wheat crop. The situation is the same for SCARP and NON-SCARP areas though it seemed more aggravated in SCARP region. Based on this, he proposed flat rate policy that would ensure more recovery of O&M cost from SCARP region because of the availability of additional water resulting in higher cropping intensities.

Table 17. Per acre comparison of current water charges with estimated water charges in non-scarp and scarp regions of Punjab and Sindh provinces.

		Non-SCARP Region			SCARP Region		
Province	Crop	Current Water Charges	Estimated Water Charges	Flat Rate	Current Water Charges	Estimated Water Charges	Flat Rate
Punjab	Wheat	21.6	36.07	48.24	43	173.13	213.51
Sindh	Wheat	20.62	54.32	79.90	20.62	111.25	246.55

(Source: Chaudhry, 1988).

3.3.4 Machinery

Jehangir and Ali (1997) while using the Cobb-Douglas model discussed that main reason for the low productivity of the wheat yield in the Rechna Doab , Punjab, Pakistan was that majority of the farms had poor access to modern equipment and machinery that resulted in poor land preparation. They also found that the tractor usage was higher in medium farms as compared with the small and large farms for different field operations in the wheat production.

3.3.5 Land Ownership and Size

Ahmad and Chaudhry (1996) conducted a study on wheat productivity differential between Pakistan and Indian Punjab. They concluded that ownership of land was restructured on compulsory basis in Indian Punjab that provided them with equitable ownership along with efficient and viable agriculture.

P.A.R.C. (1984) based on field experiment and surveys collected data found that there lied significant yield gaps regarding wheat in between Irrigated and barani areas. It meant that a significant increase in yield and production could be tapped by using inputs in recommended dosages. More important is the fact that the yield in barani areas can be increased more because of already achieved low level of yield. However, this point cannot be over emphasized due to barani areas dependence on rainfall (Table 18 & 17).

Table 18. Yield gap for wheat crop of the rabi (1981-82).

Area	Farmer Input Level	Recommended Input Level	Gap (kg/ha)	Unachieved Potential (%)
Barani	2154	3353	1199	56
Irrigated	2644	3814	1170	49

(Source: PARC, 1984).

Table 19. Yield gap (kg/ha) for wheat crop based on farm size and tenure in 1981-82.

	Category	Average Yield	Potential Yield	Gap
Farm Holding	Small	2560	3674	1144
	Medium	2412	3855	1443
	Large	2597	4144	1547
Tenure	Owner	2432	3632	1120
	Tenant	2622	3939	1317
	Owner cum Tenant	2617	3817	1200

(Source: P.A.R.C., 1984).

3.3.6 Credit

The "Report of National Commission on agriculture, (1988)" diagnosed lack of credit as a major constraint towards adoptability of modern techniques and inputs, particularly for small farmers. It also identified large farmers and farmers of Punjab as the main beneficiary of the credit facilities offered by banking institutions. Table 20 showed the per hectare availability of the credit in Pakistan. The information painted a situation in which an annual increasing supply of credit was evident.

Table 20. Per hectare availability of institutional credit in Pakistan.

Year	Total Credit (Million Rs)	Cropped Area (Mha)	Per Hectare Availability (Rs)
1952-53	4	12.09	0
1959-60	88	11.69	6
1969-70	155	16.77	9
1980-81	4028	19.33	208
1981-82	5102	19.78	258
1982-83	6315	20.13	314
1983-84	8679	19.99	434
1984-85	9674	19.92	486
1985-86	13147	20.09	654

(Source: Pakistan, 1988).

Ali et al. (1984) investigated the reasons for lower use of the credit facilities provided by the government's loaning institutions. They found that in barani areas more than 50 percent farmers did not need the credit for purchasing inputs for their crops where as about one-third though that loaning procedure is complicated and credit use is risky. On the other hand in irrigated areas, about 50 percent of the farmers did not get credit due to complicated loaning procedures although interest rate was also perceived high by about one-fifth of the farmers (Table 21).

Table 21. Reasons for lower use of credit (figures in percent).

Reasons	Barani Areas	Irrigated Areas
Not Needed	55.1	24
Loaning Procedure Complicated	31	51
High Interest Rate	-	19
Credit Use Risky	31	11

(Source: Ali et al., 1984).

Malik (1999) found that household with input credit and farm credit have shown significantly higher consumption pattern when compared for the three lowest consumption quintiles. He also found that amount and number of loans from institutional sources increased significantly from lowest to highest expenditures quintiles. Moreover, the poor were heavily relied on non-institutional financial intermediaries for their credit needs. Interestingly, friends and relatives were also an important source of credit, but for richer farm households than for the poor. He also pointed out the draw back of benefiting the large and rich farmers through subsidized credit, as was the policy of government for gearing up the green revolution technology.

Qureshi (1993) found that Pakistan's success in replacing non-institutional sources through government's supply led approach over the last thirty years was remarkable. The institutional credit increased from 10 percent to 31 percent during 1973 to 1985 period. He also mentioned that despite this impressive increase in availability of institutional credit, only 6 percent of the cultivator household had access to this. Small farmers were the most deprived class in this case who had little or negligible access to institutional credit.

3.4 Policy Packages and Regulations

Mehmood and Walters (1990) argued that both slow and cumbersome procedures for certification and restrictions on the import of seed for breeding and testing restricted the scope of spread of certified seed availability and spread in the agricultural sector. They suggested a single authority for seed variety testing and registration, certification, quality control, variety protection, and promotion. They also stressed on the need to declare seed industry as high priority industry with program of incentives for promoting it. Moreover, investment deregulation, availability of credit, and import regulations must be addressed in this regard.

Akhtar et al. (1986) argued that keeping in view the widespread cultivation of old as well as banned varieties of wheat and their higher susceptibility towards rust and smut, statutory regulations would help a lot for controlling and improving the situation for better tomorrow.

Khushk et al. (1989) opined that important changes in developing and extending wheat varieties were the need of the time. In order to improve the situation, specific wheat varieties for specific environment should be evolved. In addition, special statutory regulations were needed in order to bring down the acreage under the banned varieties of wheat accompanied with high susceptibility risk of rust. Nevertheless, this policy would work if backed by extensive and effective seed distribution system.

3.5 Research and Extension Services

Ahmad and Chaudhry (1996) found that poor infrastructure and separation of agricultural education from research and extension kept farmers of Pakistan' Punjab from the road to success as compared with their counterparts in Indian Punjab. Moreover, inadequate funding for research proved a big hurdle in the development of Pakistan agriculture with not offering breakthroughs in different fields of agriculture. It was also found that Indian farmers were practicing management and cultural practices in a much better and efficient way than Pakistani farmers. It was suggested that improvements in agricultural extension services for adoption, use, and management of key farm inputs might lead Pakistani farmers also towards path to prosperity.

Ahmad et al. (1988) by employing Probit Analysis estimated that the farmers' contact with extension services was most significant variable regarding weeds control. Radio contact also showed significant positive relationship with the dependent variable establishing its usefulness in disseminating knowledge about weeds and their control for increasing wheat production. A significant positive dummy for social status showed that influential farmers are the key person in utilizing the technological advances with in village community. This also throws light on presence of better links between influential farmers and extension services.

Altaf (1994) discussed that Pakistan's current extension service was designed for subsistence agriculture. At that time private sector was not involved in providing agrochemicals and other inputs to the farmers. However, things were changed and role of extension services had become primarily as a knowledge supplier. So, it was felt to retrain the extension personnel in order to cop with the needs of the time. This would help make them more effective in conveying farmers the much-required knowledge and will eventually improve the adoption process in case of modern technology of far more improved agricultural science. He also stressed that in order to make the extension services as an efficient and vital tool, new type of extension services and personnel might be needed.

4. CONCLUSION AND RECOMMENDATIONS

Proper land leveling and timely sowing of wheat crop is inevitable for achieving potential harvest. It is recommended to complete sowing by November 20. Delay in sowing after this date will result in loss of production. Moreover, delayed sowing required more seed quantities on per hectare basis than the recommended quantities. However, it was found that less than 50 percent of the farmers sowed wheat before the recommended date. Most of the times, it was due to delayed harvesting of kharif crops and insufficiently availability of time for land preparation that led to deferment of wheat sowing. Lack of access to modern equipment and machinery was also found as major reason for poor land preparation.

Adequacy and equity in provision of irrigation water for wheat is of prime importance. In general, farmers tended to irrigate wheat field 4-7 times during whole season. However, it depends on availability of water when crop is at critical stages and in required volume. The farmers with enough resources to meet the demands in time often got better yield. It was also established that farmer that occupied land near water source usually got more yield. Canal water as a main and cheap source of irrigation water is appreciated, but it was found that most of the times it was inadequate to meet the requirements. It was also found that farmers who irrigated their fields more frequently were using tubewell water to bolster the water availability in right volume and at right time to secure crop from water stress. It was found that wheat plant was more sensitive to water stress during tillering, booting, and flowering stages.

Rainfall was also found having beneficial effects on production of wheat. Before sowing, one ploughing after every rainfall was recommended in order to conserve water. It was also found that farmers in Punjab use more seed quantities per hectare with expectations of a rainfall that will solve their irrigation problem.

With the spread of high yielding varieties, higher use of fertilizer in order to maintain the soil fertility is needed for realizing potential yield and production. However, it was found that only 25 percent of the farmers were using fertilizer in recommended or near to recommended dosages. This lower use of fertilizer was attributed towards high fertilizer prices, unavailability of irrigation water, and farmers’ perception on quantity needed per acre for wheat.

Use of chemicals for seed treatment was not found prevalent in farming community. However, due to higher weed prevalence, labor shortage for weeding, and saving the soil from potential depletion of nutrients used by weeds, the farmers used weedicides. Considering the cost incurred on chemicals used for weed control, it was suggested that it should be practiced only where it was economical. However, it was found that majority of farmer did not use chemicals for weed control due to higher labor cost, or use of weeds as fodder for livestock, or because of failure to establish any linkage between high wheat yield and low weed population.

Water logging and salinity had differential effects on wheat plant at different growth stages. Soil salinity affected the plant at the germination stage and tillering stage although its hazards were found more devastating at the later one. Wheat yield could achieve the potential level only if water Table remained below 1.5 meters. Drainage of excessive water was found harmful for the crop.

High temperature affected the wheat plant at flowering and early grain filling stage. It was found that during these stages, high temperature could shorten the season and therefore led to reduction in the yield. Light irrigations, selection of optimum time for sowing, selection of suitable variety, and use of mulch might solve the problem of low wheat yield.

Crop rotation was found beneficial for weed control as well as for marinating the fertility of the soil. It was found that inclusion of Berseem crop in crop rotation had negative effect on weed growth. Wheat cultivation on the same fields for three or more years manifests weed growth. Incorporation of green manuring crop in crop rotation would accentuate soil fertility, and soil properties as well as dwindle pest incidence.

Average yield was also found linked with the size of the farm and tenancy status. It was also found that large farmers were able to get highest average wheat yield and still had the maximum yield gap when compared with their potential yield. Additionally, tenants were reaping highest average yield than owner or owner cum tenants.

Availability of agricultural credit was found important in order to make farmers capable of purchasing necessary input and equipment and machinery needed for different farm operations. However, less than 50 percent of the farmers were able to utilize this facility due to variety of reason. Most prominent of these were. i.e., credit not needed, complicated loaning procedures, high interest rate, and perception on credit use as a risk with a fear that they would not be able to achieve the perceived benefits due to many reasons. However, a variety of institutions, formal and informal, were available for credit with different interest rates.

A need for policy packages and regulations was also felt for promoting the wheat production at potential level. Distribution of certified and improved seed, quality control, variety protection, discouraging the sowing of banned varieties, etc. should be backed by proper policy package and regulations.

Research and extension was accepted as the most important factor to evolve new high yielding, low-disease susceptible, and area specific varieties along with variety of other needed traits in order to boast the wheat production from the existing land. More resources should be diverted towards exploring further horizon for increasing wheat yield through research. It was also found that extension services had a very weak linkage with farmers. Further training to extension staff and adoption of new techniques for diffusion of information in the farming community was proposed. For this very much educated and trained staff is the key to develop the strong and deep linkage with all the prevalent categories of the farmers. Role of extension services should be changed on better lines and use of radio, television, and other necessary means of communication should be increased.

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