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PRODUCTIVITY AND PROFITABILITY OF BARANI WHEAT UNDER CHEMICAL AND ORGANIC FARMING SYSTEMS

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ABSTRACT: Organic wheat production was initiated at the National Agricultural Research Centre (NARC) during 1998-1999. Data of wheat grown using chemical fertilizers for the same period were obtained for wheat productivity from the Farm Operations and Services (FOS) crop registers. Water productivity of *barani* organic *desi* wheat (C591) grown at NARC was computed using the data of last 10 years (1998-08), which revealed variation from 1.98 to 0.29 kgm^{-3} of seasonal rainfall. The correlation between seasonal rainfall and water productivity is very high (0.93). There is a strong correlation between seasonal rainfall and yield of *barani* wheat. The yield of *barani* wheat grown using chemical fertilizers varied from 0.41 to 3.21 t ha^{-1} represents an eight-fold variation in the wheat yield of last 10 years (1998-08). There were almost three years when the yield was higher than the mean yield and three years when yield was lower than the mean yield by around 1.0 t ha^{-1}. Economic analysis revealed that the average net return was Rs. 6744 ha^{-1} with minimum loss of Rs. 7674 ha^{-1} during 2000-01 to a gain of Rs. 20822 ha^{-1} during 2004-05. The analysis of cost of production indicated that the increase was largely in the cost of tillage and harvesting due to increase in the price of diesel fuel and renting cost of farm machinery. The average net return from *barani* wheat using chemical fertilizer is Rs. 1.22 million, on an average the benefit and cost ratio was 1.28, which means that 28 % of the total cost is realized back in the form of net returns. Out of ten years, the barani wheat production using chemical fertilizer was profitable in six years.

Key Words: Wheat; Productivity; Profitability; Chemical Fertilizers; Organic Fertilizers; Crop Yield; Economic Analysis; Pakistan.

INTRODUCTION

Wheat is the most commonly grown cereal in farming systems. Organic wheat is adapted to a range of climatic and soil conditions so it suits many of the mixed farming areas. Organic wheat production requires attention to soil fertility, rotation, agronomy, and grain storage to ensure product quality and marketability.

The basis of a successful organic grain crop is the fertility of the soil in which it is grown. Soil fertility is based on the physical, biological and chemical components of the soil environment. Physical soil fertility in an organic farming system can be promoted by having an adequate supply of organic matter through green manuring and pasture phases, good soil structure through minimizing cultivation, moisture retention with good drainage, having sufficient gas exchange around the root zone, warmth and moisture at the appropriate time. Biological fertility refers to the diversity and activity of soil organisms. Soil organisms play a fundamental role in recycling nutrients for plant growth. The soil environment that is most beneficial for these organisms to operate has plenty of oxygen (needed for aerobic microbes), a neutral pH, and organic matter that contain sufficient levels of nitrogen (Burnett and Rutherglen, 2008).

Chemical fertility refers to the level of available nutrients required for plant growth. Wheat has a requirement for phosphorus, nitrogen and potassium. The majority of soils are deficient in phosphorus with the amount of phosphorus in the soil depending on the parent material, the extent of weathering, how much has been lost

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through leaching and the level of organic matter (Burnett and Rutherglen, 2008).

Options that are available to organic producers to ensure adequate phosphorus supply for crop growth include: maintain soil pH between 5.5 and 6.5 ($CaCl_2$) to achieve maximum phosphorus availability, encourage biological activity with sufficient high quality organic matter (Mycorrhizae fungi can form symbiotic relationships with plant roots to facilitate phosphorus supply, and some bacterial species can solubilise phosphorus for plant uptake), apply allowable phosphorus inputs (based on a demonstrated need) such as reactive phosphate rock and avian deposits (Guano™). Generally, reactive phosphate rock is effective as a source of phosphorus in areas that have an annual rainfall of at least 750 mm and acidic soils. In organic farming systems the supply of nitrogen for plant growth comes primarily from the fixation of atmospheric nitrogen via the legume/rhizobia symbiosis. This can occur during a pasture phase, or by growing a legume based green manure crop that is returned to the soil. Subterranean clover and lucerne provide the highest additions of nitrogen to the soil (Burnett and Rutherglen, 2008).

Organic wheat prices vary considerably depending on the market and the quality (protein content, screenings, grain size, variety). Premiums vary depending on the season and can vary from zero (occurs rarely) to 100%. In most years, markets offer a premium of 30 - 50% above the conventional price. Organic prices for wheat do not vary as greatly as the conventional market. This may be due to many producers growing on contracts. The high premium of organic wheat is due to high proteins contents i.e. (>14%). Market prices vary seasonally (through supply) due to change in tariff rates. Freight charges vary depending on the market and can be included as a delivered price for some companies, whereas others pay extra depending on the location (Born, 2005).

The information available from different authors on organic markets and the organic wheat market indicates that it is a growth market in the short and medium term where good price premiums are available for quality produce in the right seasons. The market however is highly competitive. Current strong competitive suppliers are the United States of America, Canada, Argentina, Australia and several European countries. The competition is expected to increase considerably due to increased production from the EU, but there is also a potential for major increase in low-cost of production from eastern and central European countries (ITC, 1999; CBI, 2002; McCoy and Parlevliet, 2001; Greene and Dobbs, 2001). The world organic area in different continents comprises: Oceania 7.7 mha, Europe 4.3 mha, Central and South America 3.6 mha, North America 1.3 mha, Asia 0.094 mha and Africa 0.06 mha. In Asia area under organic farming is fractional. Asian countries provide major food production and maximum cropped area, thus there is a potential to increase the area under organic farming by many fold (Yussefi and Willer, 2002).

Organic production generally has to adhere to the same production standards as conventional production. Certification is an added requirement for organic production. Organic standards are set through negotiations between producers, consumers and the International Federation of Organic Agriculture Movements (IFOAM). Standards and subsequent certification protect consumers against counterfeit products. They also protect producers against unfair competition. Different standards are defined in different countries, and producers have to determine what standards are valid for their own country. In production for export, standards should be recognized in the target country, and appropriate certification should be arranged for that purpose (FAO,2003).

The area of *barani* wheat in Pakistan is 1.244 million hectare (mha). Out of this, 0.71 mha is in Punjab (GoP, 2007; 1991; 1981) representing the largest area under *barani* wheat due to higher rainfall. There is a declining trend in the area of *barani* wheat. It has reduced by 21% in Pakistan and 30% in Punjab since 1970-71. This reduction is largely due to the shift from *barani* wheat to irrigated wheat because farmers have installed dug wells and shallow tubewells to supplement water to reduce the risk of crop failures during dry spells and droughts. In addition, there are now 35 small dams and over 1600 mini dams in the *barani* areas of Punjab, which showed the rising trend of micro-irrigation development. The supplemental irrigation may have larger input in future for sustaining *barani* wheat in areas where water can be made available both from surface and groundwater sources (Ahmad et al., 1999; Ahmad et al., 2004).

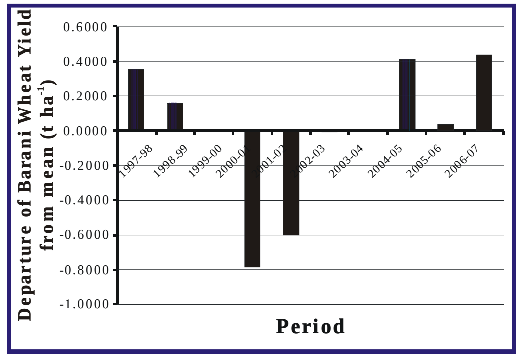

Figure 1. Departure of yield of *barani* wheat in Punjab from that of the mean yield

There is a clear rising trend of yield of *barani* wheat in Punjab, where it has increased from 0.36 t ha^{-1} in 1970-71 to 1.76 t ha^{-1} during 2006-07 (GoP, 2007; 1991; 1981). This five-fold increase in yield during the last 36 years is significant and largely contributed to better use of quality seed of improved cultivars, land leveling and bunding of fields due to the availability of heavy tillage and earth moving machinery (tractors and bulldozers), use of organic manures and chemical fertilizers, precision planting using drills, weed control and better harvesting and threshing facilities.

Land leveling and field bunding is one of the major factors contributed in managing water for *barani* wheat. Although, there were temporal variations in yield due to changes in occurrence and distribution of rainfall but there was a clear rising trend in yield of *barani* wheat. The best fits were plotted using polynomial function for the yield trend line. The departure from mean yield of *barani* wheat in Punjab indicated that in the last 10 years, the yield of *barani* wheat in four years was less than the mean yield. This is a clear indicator of risk associated with the yield of *barani* wheat in Punjab (Figure 1). The average yield of *barani* wheat during 2006-07 was 1.76 t ha^{-1}, whereas the average irrigated wheat yield during the same year was 2.76 t ha^{-1}. The 57% increase in irrigated average yield of wheat is largely due to the input of irrigation, which provided an opportunity to use higher doses of chemical fertilizers as there was less risk associated from that of *barani* wheat due to the failure of rainfall (Ahmad et al.,1998; GoP, 2007).

The research studies conducted in *barani* areas of Punjab indicated that farmers are normally reluctant to use chemical fertilizers due to uncertainity posed by failure of rainfall resulting in a dry spell. In dry years, the farmers even do not have harvests to justify the use of chemical fertilizers, which require higher and certain amount of water (Ahmad et al., 1999; Ahmad et al., 2004).

In Pakistan, the current cultivated land is 22 mha, of which 19.59 mha are irrigated. Thus, only 2.41 mha are classified under *barani* farming. The continuous reduction in *barani* cropped area is largely due to lack of appropriate technology and practices for sustainable farming systems (GoP, 2007).

Punjab in general can be considered as a wheat secure province. Within Punjab, 20 out of 34 districts are wheat surplus, while 10 fall in wheat sufficient zone and 4 are deficit districts. The need of wheat deficit districts could be catered by the province itself. In fact, the 20 surplus districts are the breadbasket of Pakistan. Rawalpindi and Jhelum districts are the part of the *barani* region of Punjab. The rest of the districts having sufficient production in wet years may succumb to wheat insecurity in dry years. However, it can be safely presumed that Punjab can easily meet demand of four wheat deficit districts along with any additional shortfall (SDPI, 2003).

The initiation of organic wheat farming at the National Agricultural Research Centre (NARC) on a large scale during *rabi* 2008-09 was a motivation to analyze the *barani* wheat production under both the chemical and organic contexts. This study is aimed to raise some of the challenges rather than presenting solutions for *barani* wheat in Pakistan. The cost effective technologies for organic farming will be available in due course of time.

MATERIALS AND METHODS

The paper is based on the analysis of field data collected from NARC, Islamabad both for organic wheat and wheat grown using chemical fertilizers. Thus, the methodology is based on the analysis of historical secondary data (1998-08) collected from NARC for wheat, seasonal rainfall, *barani* organic wheat yield, *barani* wheat yield grown using chemical fertilizers, input costs, price of wheat and other inputs.

The seasonal rainfall data for the 10 years was computed considering the crop growing season length based on planting and harvest dates. Rainfall data collected at Water Resources Research Institute, NARC, Islamabad meteorological observatory were used. The same data were used for both the organic and chemical fertilizer grown wheat during 1998-08.

No chemical fertilizer was used for organic *barani* wheat. During the *kharif* seasons of 1998-08, green manuring was done using Jantar at least once out of three years. The crop stand varied based on the rainfall received during the *kharif* season. The yield of organic wheat was collected from whole of the area planted instead of samples. Therefore, no replications were taken. The area planted under *barani* organic wheat varied from 1 to 5.5 ha during the wheat growing season. The 10 years data also constituted 10 repeats, which is a sound statistical design, when data of population is used instead of sample.

For the *barani* wheat grown using chemical fertilizer, low level of fertilizer was applied. The fertilizer use was almost same every year where two bags each of urea and DAP were used per ha. The fertilizer used during the wheat growing season was close to 64:46 (NP) kg ha^{-1}. The area planted for wheat increased from 42 ha to 224 ha per annum during 10 years. As the area planted was large, there was no need to take any replication. Furthermore, the data for 10 growing seasons during 1998-08 provides 10 repeats in statistical design. Thus the experimental design was strong enough as data of population was taken instead of sample.

Data collected for rainfall, yield of organic and chemically grown wheat, inputs and inputs cost, price of wheat for the 10 years (1998-2008) were analyzed using concepts of rainfall-productivity relationship, water productivity, gross returns and net returns. Variables include expenditures made on purchase of fertilizers, cost of tillage operation, seed, harvesting, along with the expense made on the labor wage payments, area used for wheat production, yield and prices of straw and wheat and land rent. Descriptive statistical analysis was made especially for the correlation between various parameters.

RESULTS AND DISCUSSION

Water Productivity of *Barani* Organic Wheat

Water productivity of *barani* organic wheat, at NARC was computed using the 10 years' data. The wheat cultivars C591 was grown, which is drought tolerant but having lower yield potential than the high yielding wheat cultivars grown under chemical fertilizer regime. The water productivity of organic Desi wheat (C591) varies from 1.98 to 0.29 kgm^{-3} of seasonal rainfall. The higher value of 1.98 kgm^{-3} is very high because in a dry year crop extracts water from deeper depths and soil moisture differential between planting and harvest dates is positive. Further C591 is drought tolerant cultivars and perform extremely well under low rainfall regime. The data indicated that water productivity of 0.70

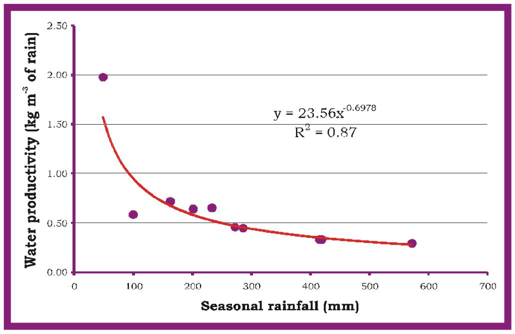

Figure 2. Water productivity of *barani* organic wheat at NARC during 1998-08

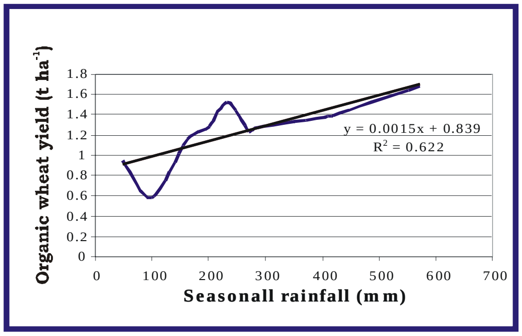

Figure 3. Barani organic wheat yield with seasonal rainfall at WRRI during 1998-08

kgm^{-3} can be achieved with water use of 150-200 mm, which is much less than the high yielding varieties under chemical fertilizer use. The correlation between seasonal rainfall and water productivity is very high (0.93). The water productivity is higher in low rainfall years, whereas it is lower in high rainfall years rather almost half of the high yielding varieties under chemical fertilizer regime. The data revealed that rainfall in the range of 150-200 mm is essential to accomplish water productivity of *desi* wheat in the range of 0.6 to 0.7 kgm^{-3} (Figure 2). The results are inline with the water productivity estimated for wheat for various countries by WB (2005) and IWMI (2003).

Seasonal Rainfall and Yield of *Barani* Organic Wheat

The Water Resources Research Institute (WRRI), NARC under the Natural Resources Division, PARC Islamabad has been involved in the long-term trials of organic wheat, where no chemical fertilizer, herbicide or pesticides were used for the last 15 years. The data for the first five years was not taken in the analysis as supplemental irrigations were also applied. Further, people do regard that at least five years later of the start of organic farming one can easily claim that now the produce is free of any chemical fertilizer because some of the traces might be available in soil as fixed form of chemical fertilizers. The yield of *barani* organic wheat at NARC varied from 0.95 to 1.68 t ha^{-1} under completely organic conditions, where only green manuring was done after the harvest of wheat crop at least one out of three years (Figure 3).

The variability in yield of organic wheat was less from that of chemical agriculture. Therefore, organic agriculture has higher capacity to adjust with the extreme droughts (Ahmad et al., 2004). The relationship between seasonal rainfall and yield of *barani* organic wheat was computed which is as strong as the linear function provided value of R^2 of 0.62, which is reasonably high indicating that 62 % variation in organic wheat yield is explained by the seasonal rainfall. The correlation between the two was also high. Three out of ten years were having yields of less than the mean year, whereas four years were having higher yields from the mean year. Rest of the three years was having slightly higher yields from that of the mean yield. This shows that variability in yield of organic wheat is much less from that of chemical wheat.

Seasonal Rainfall and Yield of *Barani* Wheat at NARC

There is a strong correlation between seasonal rainfall and yield of *barani* wheat. The yield of *barani* wheat grown using chemical fertilizers from 0.41 to 3.21 t ha^{-1} represents an eight-fold variation in the wheat yield of last 10 years (NARC-FOS, 2008). This variability in yield of *barani* wheat was due to associated variation in seasonal rainfall from 48 mm to 572 mm (NARC-WRRI, 2008). The temporal analysis of yield of *barani* wheat of from 1998-99 to 2007-08 indicated that supplemental irrigation is essential to ensure sustainable production due to erratic distribution of rainfall during seven out of ten years.

Departure of Yield of *Barani* Wheat from the Mean Yield at NARC

The yield of *barani* wheat at NARC was higher than average yield of irrigated wheat for two out of ten years. Five out of ten years had yield of *barani* wheat of less than the mean yield, only four years had significantly higher yield than the mean yield. The departure from the mean yield was also very high. There were almost three years when the yield was higher than mean and three years when yield was lower than the mean yield by around 1.0 t ha^{-1}.

The area of *barani* wheat using chemical fertilizer at NARC is not correlated with the seasonal rainfall, because at the time of planting there was no prediction for the probable rainfall.

Water Productivity of Barani Wheat using Chemical Fertilizer

The data of the rainfall is taken from WRRI, NARC, Islamabad and water productivity for the wheat was calculated. Water productivity is a ratio of wheat yield per unit of water and expressed as kg m^{-3} of seasonal rainfall. There is differential of soil moisture as the difference between the soil moisture at planting and harvest dates. As the data of soil moisture was not available, therefore soil moisture differential between planting and harvest dates cannot be estimated. The seasonal rainfall is fully available for consumptive use of water for wheat, whereas the soil moisture differential between planting and harvest dates is positive during the dry years. The water productivity varies from 1.16 to 0.58 kg m^{-3} of seasonal rainfall. The higher value of 1.16 kg m^{-3} is not precise because in a dry year crop extracts water from deeper depths as soil moisture differential between planting and harvest dates is positive. The data indicated that water productivity of 0.80 kg m^{-3} can be achieved with water use of around 250 mm. The correlation between seasonal rainfall and water productivity is reasonable (0.57). The water productivity is higher in low rainfall years, whereas it is lower in high rainfall years. The data further revealed that rainfall in the range of 200-300 mm is essential to achieve water productivity from 0.7 to 0.8 kg m^{-3}, which is reasonably high (Figure 4). The results are in-line with the water productivity estimated for wheat for various countries by WB (2005) and IWMI (2003).

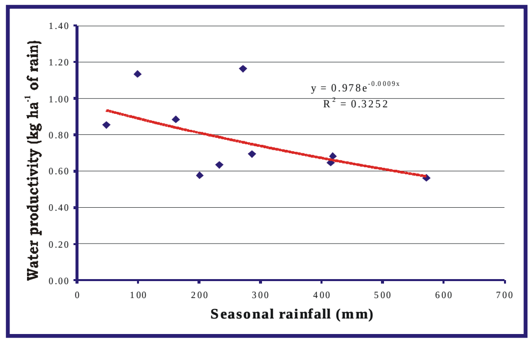

Figure 4. Water productivity of wheat grown on chemical fertilizers at NARC during 1998-08

Economic Analysis of *Barani* Chemical Wheat at NARC

An economic analysis was conducted to evaluate the cost of production, gross returns and net returns of *barani* chemical wheat during the last 10 years. This section is an attempt to calculate the gross and net returns and benefit-cost ratio of chemical wheat in the last 10 years. The data were used to develop methodology for the economic analysis of *barani* chemical wheat.

In the economic analysis, historical data of area and production of wheat under *barani* conditions were provided by the Directorate of Farm Operations and Services, NARC, Islamabad. In addition, data of price of wheat per 40 kg and other variable costs (seed, fertilizers, weedicides, tillage, and harvesting) were collected for estimating gross and net returns per unit area.

Net economic returns were computed for *barani* wheat as gross returns minus cost of all variable inputs. Variable cost in the production of wheat includes cash and imputed costs. Cash cost includes variable cost of inputs and imputed cost includes largely the labor cost (skilled and un-skilled). The economic analysis of *barani* chemical wheat at NARC would provide an insight about economic efficiency of wheat. However, a change has been made during 2008-09, where experimental treatments have been employed for the production of organic wheat to develop and synthesize technology for the farmers.

Gross and Net Returns per Unit Area

The net returns per unit area were computed using the following equation

$NR_t = GR_T - VC_T$

where

NR_t = Net returns gained from the production of wheat per unit area (Rs. ha^{-1}) for a given year covering all the marketable products like grain and straw;

GR_T = Gross returns obtained by multiplying the prices of marketable products with the production per unit area (Rs.ha^{-1}) for a given year plus returns obtained from the straw;

VC_T = Variable cost which is obtained by adding all the input costs per unit area (Rs. ha^{-1}) for a given year.

The gross returns per unit area can be computed using the following equation.

$GR_T = WP_t + SP_T$

where,

WP_T = Gross return from wheat grain per unit area for a given year (Rs. ha^{-1}).

SP_T = Gross return from straw production per unit area for a given year (Rs. ha^{-1}).

For the quantity of the straw the wheat grain and straw ratio is 1:1.5. The price of straw is calculated as 30 % price of the wheat grain. The returns from straw are obtained by multiplying the quantity of straw with the price. Average returns obtained in monetary terms are 8338 Rs. ha^{-1}.

There are variations in gross and net returns of production of *barani* wheat per unit area. The average net return is Rs. 6744 ha^{-1} with minimum loss of Rs. 7674 ha^{-1} in 2000-01 to gain of Rs. 20822 ha^{-1} in 2004-05. This large variation in net return per unit area is primarily due to the variability in seasonal rainfall. The extreme variability in gross and net return per unit area is a clear indication that there is a need to conduct analysis of fertilizer cost because in dry years the cost of fertilizer may not be recovered by the farmers. NARC is relatively in a privileged condition, as land is normally fallow during the *kharif* season, whereas farmers in high rainfall areas grow crops during both the seasons.

Labour Cost

It is difficult to calculate the full labour cost involved in wheat production at NARC, Islamabad. The time of scientists, engineers and technicians used in wheat production is not included as they are not exclusively involved in wheat production. Furthermore, the cost of tillage, harvesting and threshing is computed based on commercial rates prevailing in the market, therefore, cost of technicians, drivers and helpers is included in the pro-rata cost of tractor and combine harvester used in the economic analysis. Therefore only operational and seasonally hired labor was accounted for the current economic analysis. The average seasonal labor cost during the last 10 years comes to Rs. 380700 per annum (Fifteen laborers were hired for 180 days, representing total of 2700 labor days. Daily labor wage rate of Rs. 60 per labor was used for 1998-99 and Rs. 230 labor per day for 2007-08).

Land Rent

The land charge is based on rent equivalent. The land rent of 620 kg ha^{-1} of wheat is used for the *barani* lands of NARC. The average land rent for the whole period of analysis was 2150 maunds in aggregate worth of Rs. 0.80 million or Rs. 5665 ha^{-1} basis. The rate of land rent (15.5 maunds ha^{-1}) is constant in kind during the period of analysis, because wheat prices are already adjusted to the inflation.

Cost of Fertilizer

Both the nitrogenous and phosphatic fertilizers were applied during the last 10 years. Mostly urea and di-ammonium phosphates were used for providing N and P_2O_5 to wheat crop, whereas Nitrophos and single super phosphates were also employed. The price of actual types of fertilizers was used since 1998-99. Actual data of fertilizer applied during the last 10 years were collected from NARC, Islamabad. There is an increase in fertilizer cost per unit area due to rising prices of chemical fertilizers. The cost of fertilizer per hectare during 2007-08 was Rs. 8473 ha^{-1}, almost equivalent to 0.90 t ha^{-1} or 9 maunds per acre of wheat grain (Figure 5).

This is an alarming signal for the R&D agencies (i.e. PARC) and the decision makers. The current price indicates that in the dry years farmers will not be even able to recover the cost of fertilizer. Therefore, there is an urgent need to address the issue of high cost of fertilizer and profitability of *barani* wheat.

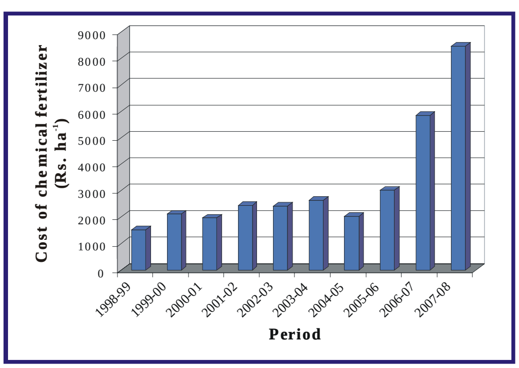

Figure 5. Cost of chemical fertilizer per unit area for *barani* wheat at NARC during 1998-08

Other Variable Affecting Cost of Production

The others variable that affect the costs of production are:

Tillage Cost

It started increased since 1998-99 primarily because of rise in the prices of diesel fuel. Thus, energy is going to be one of the major concerns in wheat production in *barani* environments. The cost of tillage has increased from Rs. 1800 ha^{-1} in 1998-99 to Rs. 5600 ha^{-1} in 2007-08, representing a three fold increase.

Seed Cost

It was also increased since 1998-99 primarily due to increase in support price of wheat. Increase in support price of wheat also resulted in increased price of wheat seed. The cost of seed has increased from Rs. 741 ha^{-1} in 1998-99 to Rs. 1930 ha^{-1} in 2007-08, representing a 2.5 folds increase.

Harvesting Cost

Harvesting cost during 1998-99 was Rs. 1377 ha^{-1}, which was increased to Rs. 6209 ha^{-1} during 2007-08 primarily due to the rise in price of diesel fuel and increased labor or machine harvesting cost. The increase was almost 4.5 folds.

Weedicides

They were used only twice in ten years and cost was Rs. 556 ha^{-1} and Rs. 388 ha^{-1}. This shows that weedicides use was minimal. However, weeds are more in wet years compared to the dry years, especially early rainfall induces more weed infestation because once the crop has achieved full effective cover weed infestation is less or negligible.

The analysis of cost of production indicated that the increase was largely in the cost of tillage and harvesting, which was due to the increase in the price of diesel fuel and renting cost of farm machinery. The other cost is the cost of fertilizers. Thus, both the fertilizer and energy costs are the major contributors affecting the profitability of *barani* farming. The energy use in agriculture is now critical; it is mainly used in pumping of groundwater and all sort of farm operations including the haulage. However, some of the agricultural wastes can be used for the generation of bio-energy from crop residues and animal wastes. Energy budgets for agricultural production systems can be used as building blocks for the assessment of potential options where major savings in the use of energy can be made either through improvement in efficiency or by managing the demand.

Total Gross and Net Returns

The average gross return from *barani* wheat was Rs. 4.01 million, whereas the minimum and maximum gross returns were Rs. 0.41 and Rs. 9.36 million respectively. The average net return from *barani* wheat is Rs. 1.22 million, whereas the minimum and maximum net returns are loss of Rs. 1.17 million and gain of Rs. 4.70 million, respectively. The wide variability in total net returns from *barani* wheat is largely due to the variation in seasonal rainfall – in terms of both occurrence and distribution. The highest gross and net returns are of Rs. 9.36 million and Rs. 4.70 million, respectively for 2004-05. This shows that in a wet year, the net returns were almost double the cost of production of *barani* wheat at NARC, Islamabad.

Benefit Cost Ratio

For the analysis of the benefit-cost ratio, obtained by dividing the gross value of of *barani* wheat by the total cost of production following economic conditions should be considered.

Break even is the situation where marginal cost is equal to marginal returns.The ratio of benefit-cost is equal to 1 in this case. In this situation there is no profit and no loss.

Shut down condition is where marginal cost is greater than the marginal returns and the value of the benefit and cost ratio is less than 1 showing the loss.

Economic profit is the situation where marginal returns are greater than the cost and the ratio of benefit and cost is greater than 1.0 depicting the economic profit.

On an average the benefit and cost ratio was 1.28 showing that 28 % of the total cost is realized back in the form of net returns during the last ten years. The annual benefit-cost ratio suggests mix behavior. The benefit-cost ratio of less than 1.0 was observed in three out of ten years, where even the cost of production was not recovered. In 2005-06 the benefit-cost ratio was 1.0 indicating a situation of break-even. Thus in six out of ten years the *barani* wheat production was profitable. The loss in wheat production during three out of ten years was largely due to inadequate rainfall or erratic distribution during the wheat growing season. During 2002-03 to 2004-05, the net benefits almost equal the cost of production (Table 1).

Table 1. Benefit-cost ratios of Barani wheat at NARC

Years	Benefit/Cost Ratio
1998-99	0.77
1999-00	1.24
2000-01	0.37
2001-02	0.83
2002-03	1.95
2003-04	2.01
2004-05	2.01
2005-06	1.00
2006-07	1.37
2007-08	1.21

Seasonal Rainfall and Benefit-Cost Ratio of *Barani* Wheat

It is not possible to estimate the marginal cost and marginal value of wheat when seasonal rainfall is a constant in a given year. Therefore the benefit-cost ratio was related with the seasonal rainfall during the growing season length of wheat. The third order polynomial function was fitted to the curve with R^2 of 0.725, which is reasonably high. The benefit cost-ratio indicated that the benefits start reducing when seasonal rainfall exceeds 400 mm, which is more than the consumptive use requirement. This is sufficient to double the return of the production cost, as the benefit-cost ratio was almost 2 at 400 m and then starts reducing (Figure 6).

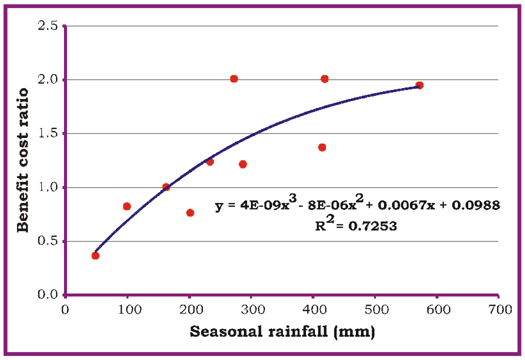

Figure 6. Seasonal rainfall and benefit cost ratio for *barani* wheat at NARC during 1998-08

Challenges of *Barani* Organic Wheat

The analysis of *barani* wheat yield in Pakistan, Punjab and at NARC (both chemical and organic) for the last 10 years helped to articulate the challenges related to *barani* organic wheat at NARC, for example:

What should be the target yield of barani organic wheat at NARC located in the high rainfall regime? As the average yield of *barani* wheat in Punjab was around 1.76 t ha^{-1} during 2006-07, therefore, *Barani* organic yield should be around 2.0 t ha^{-1} for NARC.

How the cost of fertilizer for yield of 2.0 t ha^{-1} can be reduced, as it is 50% of the gross returns? The cost of chemical fertilizers is now very high (Rs. 9000 ha^{-1} or equivalent to 1.0 t ha^{-1} of wheat grain), therefore organic fertilization of the same level in terms of nutrients availability or use have to be developed so that profitability of wheat farming can be enhanced.

The real challenge is to engineer the cost-effective process of producing organic fertilizers at NARC in quantities required for the next kharif crop. Furthermore, engineered technology and process for formulation of bio-fertilizers (bio-fertilizer plants) are also required at the country level, which PARC can market in collaboration with the private sector. The initial work done (by scientists of WRRI) on rock phosphates analysis indicated that sulphuric acid soluble P_2O_5 is around 21-23%, which indicates that it is possible to formulate a balanced organic fertilizer using a mixture of EM compost and rock phosphate to provide balanced nutrition for organic farming. It is worthwhile to use poultry manure to have more enriched organic fertilizer. If possible, sugarcane mud can also be utilized in the process of formulating the organic fertilizer.

How the input of energy in barani organic wheat can be reduced to enhance the profitability? The rise in diesel fuel prices have disturbed the agriculture production systems in terms of seedbed preparation, planting of crops, inter-culture for weed control, foliar application of soluble fertilizers, sprinkler irrigation, harvesting and threshing. Therefore, while developing technology for organic farming, efforts must be made for having minimum tillage for seedbed preparation and other field operations so that production cost is reduced considerably. Why not residue farming be practiced at NARC? The ABEI, NARC designed machines for zero-till and residue planting be tried first at NARC. Why not ABEI, NARC works as partner in using appropriate tillage and weed control machinery? WRRI, NARC can play vital role in foliar application of bio-fertilizers, bio-fertigation, sprinkler and drip irrigation, etc.

How appropriate system of composting can be developed by WRRI so that weed seeds are destroyed completely? Other ways have to be found to eradicate weeds. All efforts are needed to clean and grade the seed of crops. The use of organic composts normally results in higher infestation of weeds due to the presence of weed seeds in the manures. Efforts are needed to address the issue of weed seeds in animal wastes so that weeds are controlled under organic farming systems.

How NARC based seed grading plant can be made functional before the harvest of wheat? The plant can be used for grain seeds, vegetables and other crops. In addition the Directorate also makes sure that storage facility for graded wheat seed is in order. The current wheat crop stand at NARC indicates that wheat seed used during 2009-10 was not effectively graded. The

NARC has a seed cleaning, grading and treatment plant (as part of Horticulture Research Institute), which must be made fully functional for cleaning and grading of future wheat and other seeds.

How to include green manuring as a part of the cropping pattern as it will be costly to provide all the required nutrients in organic form to meet the need of crops? *What are the chances to manage the wide C:N ratio in the soil after the incorporation of wheat straw*? *What options are available for quick fermentation or decomposition of wheat straw*? Similar technology will help to get benefit from green manuring. As combine harvester is used for harvesting of wheat crop and the wheat straw is normally incorporated into the soil. *How legumes can be added into the cropping pattern to fix the biological nitrogen from the atmosphere?*

It is thus concluded that water productivity of *barani* organic *desi* wheat (C591) at NARC was computed using the data of last 10 years which revealed variation from 1.98 to 0.29 kgm^{-3} of seasonal rainfall. The correlation between seasonal rainfall and water productivity is very high (0.93). There is a strong correlation between seasonal rainfall and yield of *barani* wheat grown using chemical fertilizers. The yield of *barani* wheat grown using chemical fertilizers varied from 0.41 to 3.21 t ha^{-1} represents an eight-fold variation in the wheat yield of last 10 year. There were almost three years when the yield was higher than mean and three years when yield was lower than the mean yield by around 1.0 t ha^{-1}. Economic analysis revealed that the average net return was Rs. 6744 ha^{-1} with minimum loss of Rs. 7674 ha^{-1} in 2000-01 to gain of Rs. 20822 ha^{-1} in 2004-05. The analysis of cost of production indicated that the increase was largely in the cost of tillage and harvesting due to the increase in the price of diesel fuel and renting cost of farm machinery. The average net return from *barani* wheat is Rs. 1.22 million, on an average the benefit and cost ratio was 1.28, which means that 28 % of the total cost is realized back in the form of net returns. In six out of ten years the *barani* wheat production was profitable.

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