

Chapter 3

Growth Pattern and Economic Impacts of Wheat Productivity on Punjab Agriculture

R.S. Sidhu, Kamal Vatta and Shayequa Zeenat Ali

3.1 Introduction

In recent years, the agriculture sector in India is beset with many problems. The growth in the sector, especially of crops, has stagnated since mid-1990s (Chand 2005). The growth in the agriculturally developed regions like Punjab, Haryana, etc., too has slowed down (Sidhu et al. 2005). The productivity growth of important foodgrains like wheat and rice has stagnated. Consequently, the profitability of farming has deteriorated even in the developed pockets due to which very serious problems like indebtedness and farmers' suicides have emerged (Sidhu and Gill 2006). Many factors are considered responsible for these developments, which make it a compelling case to investigate the story of growth (and deceleration) in terms of its processes, so that futuristic road map for its growth is developed to meet the challenge of growing food demand in the country.

The most important and feasible method of increasing agricultural output in future would be through raising the productivity of land by increasing the irrigated area, higher use of fertilizers, adoption of input use efficient practices, development of infrastructure and institutions such as agricultural research, extension, input delivery, credit, etc. Within India, there are large disparities in the state-wise area under irrigation, cultivation of high yielding seeds and consumption of fertilizers. The proportion of net sown irrigated area ranges from less than about 30 % in Orissa and Chhattisgarh and Madhya Pradesh to 98 % in Punjab and the fertilizer consumption varies from about 56–88 kg/ha of gross cropped area in Assam, Madhya Pradesh and Orissa to 243 kg in Punjab (GOI 2012). There is also skewed pattern of

R.S. Sidhu
Punjab Agricultural University, Ludhiana 141001, India

K. Vatta (✉) · S.Z. Ali
Centres for International Projects Trust, 910-11, Pragati Towers,
Rajendra Place, New Delhi 110008, India
e-mail: kamal@cipt.in

fertilizer consumption towards irrigated areas as well as *rabi* season (winter season). This variability points towards an enormous scope that exists to boost agricultural production through increase in the use of fertilizers along with other complementary inputs and positive input–output price policy. It was the package of irrigation-high yielding seeds-chemical fertilizers during the late-1960s, 1970s and 1980s which shifted the agricultural production system of the country on a high growth path and transformed it from food deficit to food self-sufficient nation. The question arises whether it will again be the same package, which will ensure 4 % growth of the agriculture sector as well as food security through increasing production of wheat.

3.2 Growth in Input Use and Production of Wheat in India

The pattern of growth in fertilizer use, area under high yielding seeds and irrigated area in different time periods was different but was strongly associated with one another. With the introduction of high yielding seeds of wheat on irrigated areas during late-1960s and early-1970s, fertilizer use picked up with a growth rate of 9.4 % during 1970s. As the growth in irrigated area slowed down during 1980s and 1990s, the growth in area under high yielding seeds as well as fertilizer use decelerated (Table 3.1). The growth in wheat production was strongly associated with these variables, which was facilitated by favourable input–output price policy and availability of cheap institutional agricultural credit. The growth has, however, been sluggish since mid-1990s, which became stagnant during 2000–01 and 2009–10. It appears that the stagnation in the expansion of irrigated area caused stagnation in the area under high yielding seeds and associated fertilizer use and even the greater availability of institutional credit and relative fall in fertilizer prices with respect to wheat price could not encourage production. It is thus argued that slow/no growth in irrigated area and consequent slowdown/stagnation in growth in area under improved seeds as well as fertilizer use were primarily responsible for slowdown in the growth of wheat productivity and production in the country and may have had serious implications for achieving the targeted growth of 4 % in the agriculture sector.

Table 3.1 Growth rates of fertilizer use and other related variables in India, 1970–71 to 2009–10

Period	Yield	Production	NPK use	Area under HYVs	Irrigated area	Price ratio	Short-term credit
1970–71 to 1979–80	1.87	4.31	9.39	11.62	2.67	1.20 ^{ns}	14.43
1980–81 to 1989–90	3.10	3.58	5.47	3.28	1.01	0.48 ^{ns}	13.10
1990–91 to 1999–2000	1.82	3.57	1.93	2.21	0.59	−4.59	18.88
2000–01 to 2009–10	0.69	1.90	1.26 ^{ns}	0.71 ^{ns}	−0.54 ^{ns}	−0.13 ^{ns}	24.30

Note ns means non-significant, all the other figures are significant at 5 % level

3.3 Determinants of Wheat Production in India

The pattern and growth of fertilizer use, high yielding varieties and irrigation of wheat in India during 1970–71 to 2009–10 indicated complementarities to increase wheat production. Irrigation triggers adoption of high yielding seeds, which are more responsive to fertilizer application. The combination of this package in a sequential manner helps raising productivity and production. This analysis capturing such relationships is carried out by using the following simultaneous equation models for wheat production to estimate their contribution towards growth. The error terms are assumed to be serially independent and identically distributed in such estimation. The equations were identified and subsequently estimated by using the software STATA.

$$Q_t = f(\text{NPK}_t, \text{HYV}_t)$$

$$\text{NPK}_t = f(P_t, \text{HYV}_t, \text{Credit}_t)$$

$$\text{HYV}_t = f(\text{Irri}_t)$$

where:

Q_t Wheat production (million tonnes) in period t

NPK_t Fertilizer consumption in wheat (thousand nutrient tonnes) in period t

P_t Ratio of fertilizer price to the wheat minimum support price (MSP) for period t

HYV_t Area under high yielding varieties of wheat (million ha) in period t

Irri_t Percentage of wheat area under irrigation.

The relative contribution of each determinant of production, fertilizer use and area under high yielding varieties as well as their derived impact estimated with the help of simultaneous equation model is given in Table 3.2. The adjusted R^2 was very high in all the equations of the model, indicating the robustness of the relationships. Irrigation was seen as the main driver of promoting high yielding seeds,

Table 3.2 3SLS estimates of the determinants of wheat production and related factors, India, 1970–71 to 2009–10

Particular	Production	NPK use	Area under HYVs
NPK consumption	0.24**	–	–
Price ratio	–	–0.04**	–
Area under HYVs	0.73**	1.35**	–
Short-term credit	–	0.12**	–
Area irrigated	–	–	1.08***
R-square	0.95	0.95	0.96

Note The figures are the elasticities estimated for each coefficient. ** and *** represent the significance at 5 and 1 % levels, respectively

which in turn helped increasing production of wheat directly and through promoting higher use of fertilizers. Fertilizer application was also facilitated by favourable fertilizer/output price regime, which showed a declining trend due to fertilizer subsidies, and institutional agricultural credit growth. The elasticity of area under high yielding wheat varieties to irrigation was as high as 1.08 and that of production to area under high yielding varieties as 0.73. The fertilizer use was also very elastic to high yielding seeds. The institutional credit and fertilizer price (real) also helped increasing use of fertilizers but the impact of non-price factors was stronger than that of price factors in increasing wheat production.

The process of growth and stagnation in wheat production derived through its determinants led to the same conclusions. Expansion in irrigated area resulted in a larger area under high yielding varieties of wheat in order to realize higher production and profits. Since high yielding varieties were high nutrient consumers and were thus highly responsive to chemical fertilizers, the use of chemical fertilizers increased. Recognizing the potential of high yields of wheat, the Government of India put in place the institutional and policy frame in the shape of higher output prices, fertilizer subsidies and greater access to institutional credit to encourage the use of chemical fertilizers and other modern production inputs for obtaining higher foodgrain production and meeting food demand. All these factors in combination raised wheat productivity and production in the country. This process was replicated in all the potential areas of the country. The success of this package was high in those areas, where groundwater resources were also exploited to increase the irrigation scope and intensity. Punjab represents a classic case of such policy.

3.4 Growth in Wheat Production in Punjab: A Success Story

History of agriculture is the history of evolution of mankind as well as evolution of agriculture. Human beings selected plants and animals which met their requirements. History of agriculture is replete with uncertainty due to the vagaries of weather such as floods, droughts and famines. India is also vulnerable to crop failures and famines. There were 19 famines in India between the eleventh and twentieth century and the Bengal famine of 1943 was the last one. After the era of Green Revolution that began in 1960s, India never experienced a famine-like situation, though it experienced the worst drought of the century in 1987. Punjab and Northwestern India are equally prone to crop failures, and famines recorded in the pre-partition Punjab were in 1802, 1812, 1817, 1824, 1834, 1837, 1851–52, 1860, 1868–69 and 1877–78. Despite these constraints, the region emerged as the food basket of India. This was possible due to the irrigation, land, social, legislative and institutional reforms. Punjab, with 1.53 % geographical area, contributes about 39 % wheat and 27 % rice to the central pool of foodgrains (2010–11). It was the result of technological developments in agriculture and their rapid dissemination and adoption backed by Government policy support in market, prices, input delivery and credit.

3.5 Crop Improvement Programme in Wheat

The scientific crop improvement efforts were made with thrust in increasing production of the foodgrains. Collective efforts were made by crop breeders, geneticists, biochemists, crop physiologists, agronomists, plant pathologists, entomologists, soil scientists and farm engineers to achieve transformation of the farm technology from traditional to the current levels of productivity and production. Systematic crop breeding efforts for yield increase and incorporating other desirable traits, testing of the suitable types at multi-locations and the new seeds thus developed in adaptive trials were carried out in collaboration with the state directorate of agriculture and at farmers' fields for adaptability before recommending for cultivation in the state.

Punjab Agricultural University (PAU) is a State Agricultural University (SAU), but is well knit with the National Agricultural Research System (NARS) in the Indian Council of Agricultural Research (ICAR) through All India Coordinated Research Projects (AICRP) for the development of wheat varieties for the state and the NWPZ (North West Plains Zone comprising eight states). The materials are tested in the all-India crop improvement projects in zonal evaluation by PAU and those which appear to be promising for Punjab are further tested in local adaptive trials as is done for the indigenously developed varieties at PAU. After being found suitable, these varieties are released for cultivation in Punjab or in specified areas of the state. Similarly, PAU varieties, which have the advantage in other zones, are released nationally for the benefit of the farmers of other states. Materials received from international nurseries in the collaborative programmes and found suitable are also used in the breeding programmes and the varieties thus developed or improved are recommended for cultivation in the state after adaptive trails to maximize the farmers' benefits.

Wheat research is not only focused on yield enhancement but also on plant production and protection technologies to ensure efficient resource utilization and crop protection from the incidence of diseases, weeds and pests. The priority of the research agenda continues to undergo changes depending upon the emerging issues and problems being faced by the production system. During 1960s, 1970s and 1980s, the breeding programme largely emphasized yield enhancement through improved genotypes, which were responsive to higher use of inputs. Weed management was another issue in wheat cultivation due to predominance of the weed called *Phlaris minor*. Production practices like sowing time, fertilizer application, spacing, irrigation schedule, etc., were also fine-tuned in order to maximize production. Incidence of diseases, especially rusts, is also an unending process in wheat cultivation. It is often said that rust never sleeps in wheat. During 1990s, as rice-wheat production system caused degradation of natural resources, especially soil and water, the research aimed at developing resource-efficient practices and technologies while maintaining productivity growth. Continued emphasis on natural resource conservation technologies along with yield and quality improvement in wheat is the thrust area of research in the past more than one decade. Recently, wheat research programme is also being geared up to address the challenge of heat stress, which is adversely influencing wheat

productivity under ensuing climate changes. Genetic engineering, molecular biology and biotechnology tools in wheat research are currently being applied to shorten the varietal development programme of desirable traits.

Since its inception, PAU has released 33 varieties of bread wheat, 6 of durum wheat and 3 of *triticale* for sowing under different ecological conditions of the State. Out of these, 22 bread wheat varieties and 5 of durum wheat were released at the national level. The cultivation of varieties developed by PAU is spread across all the wheat-growing zones of the country from Himachal Pradesh to Karnataka as illustrated in Fig. 3.1.

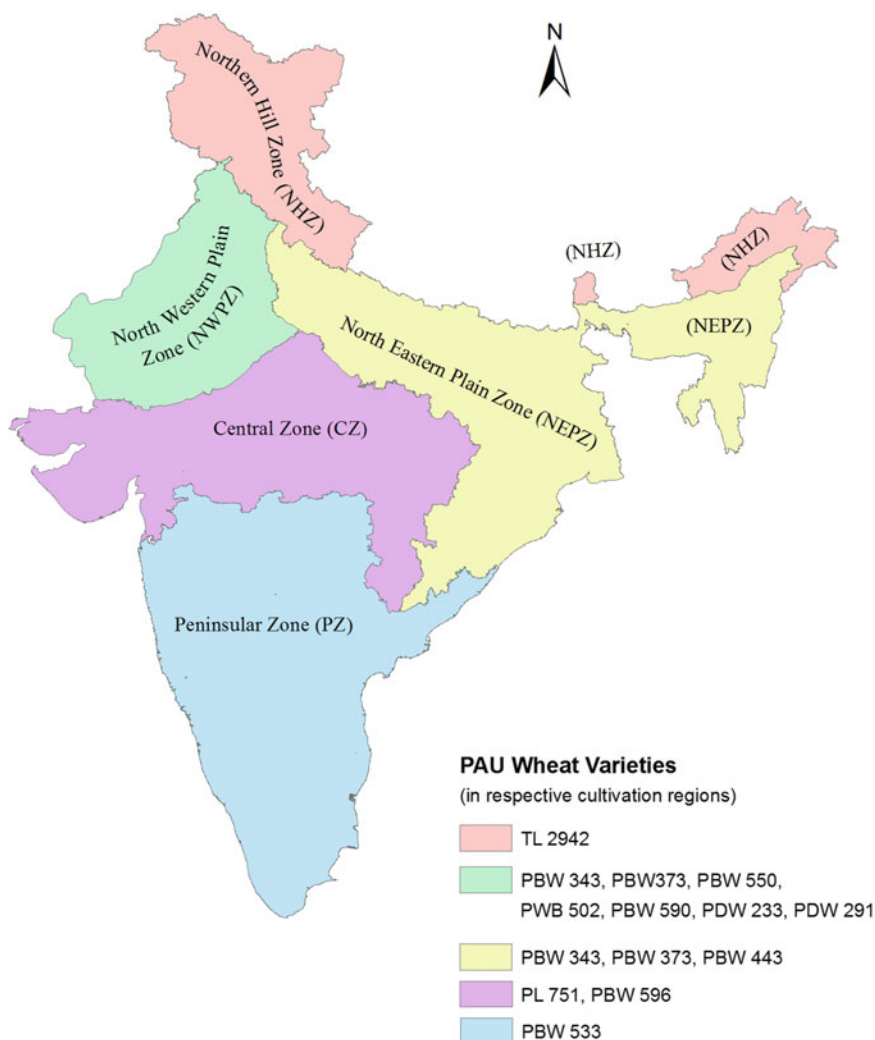


Fig. 3.1 PAU wheat varieties and the regions of their cultivation. *Source* PAU (2009a)

During 1960–61, the area under wheat cultivation in Punjab was only 1.4 million ha with the total production of 1.74 million tonnes and productivity of 1244 kg/ha. However, the area under wheat increased to approximately 3.5 million ha and the productivity increased manifold to 4693 kg/ha during 2010–11. In 1965, the first improved variety, named C 306, was released and the average yield of state was 1244 kg/ha against the yield potential of this variety at 3370 kg/ha. The release of wheat variety Kalyansona in 1970 enhanced the yield potential to 4200 kg/ha, which was further enhanced to 4680 kg/ha with the release of WL 711 in the year 1975 (Figs. 3.2 and 3.3). During the course of time, WL 711 developed susceptibility to Karnal bunt. Another wheat variety, named PBW 343, with an average yield potential of 5.42 t/ha, which was resistant to Karnal bunt and yellow as well as brown rust, was released in 1995. During 2010, a new wheat variety PBW 621 was developed by PAU, which gives around 8 % higher yield than PBW 343 and is highly resistant to yellow rust and moderately resistant to stem rust (Ug 99).

As the adoption rate of these high yielding varieties increased, the average productivity in the state went up from 2.2 t/ha in 1970–71 to 4.5 t/ha in 2000–01 due to higher use of complementary inputs like fertilizers, chemicals for control of diseases and pests as well as adoption of recommended cultivation practices in sowing, irrigation, spacing, etc. These wheat varieties, especially WL 711 and PBW 343, also became popular in other states due to their better potential. PBW 343 occupied almost 90 % of the area in the State and about 70 % (7 m ha) in North Western Plains Zone and was spread even to the Eastern parts of India. On the whole, the average annual gain in production through the genetic upgradation and higher use of complimentary inputs during the period 1965–95 was estimated to be

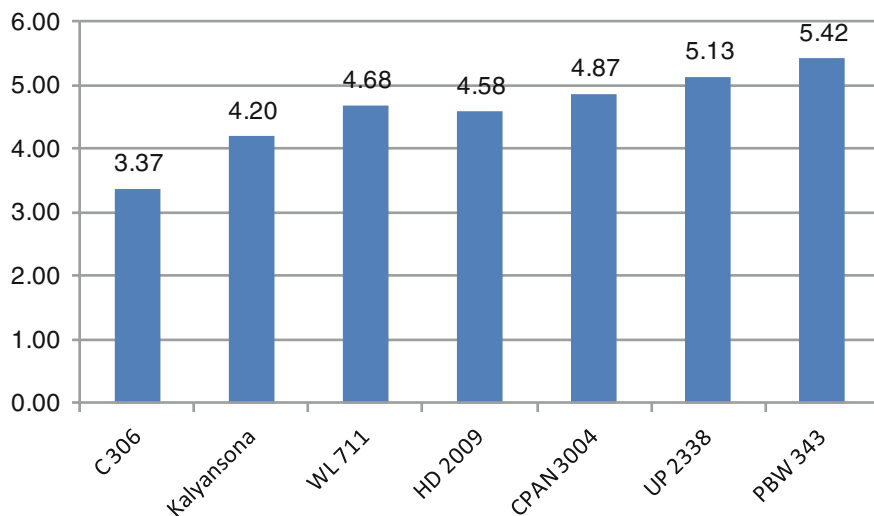


Fig. 3.2 Genetic gain for yield in North West Plains Zone yield (tonnes/ha). Source PAU (2009b)

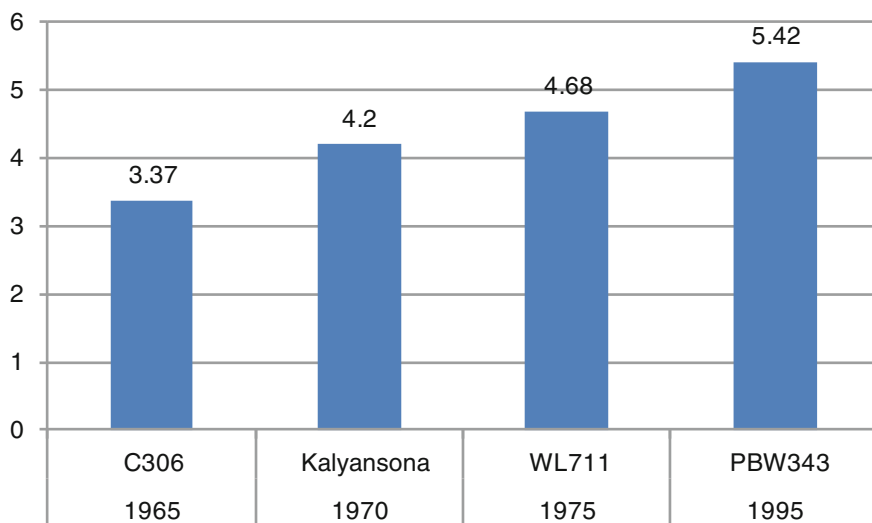


Fig. 3.3 PAU wheat varieties—Yd tonnes/hect

38 kg/ha. Presently, the variety PBW 550, released in 2007 for cultivation in the state, is resistant to yellow rust and is performing exceedingly well in the farmers' fields.

3.6 Dissemination and Adoption of New Technology

Development of technology and its dissemination is one of the important mandates embedded in the agriculture research system and state policy. This task is assigned to the Punjab Agricultural University and State Department of Agriculture. PAU implements its technology transfer model through Farm Advisory Service Scheme (FASS) at all district headquarters and Krishi Vigyan Kendras (KVKs) in collaboration with the Department of agriculture. The extension network for technology transfer has helped in achieving fast-paced adoption of new technologies and consequent transformation of agriculture in Punjab. The extension services have played an important role in the development and refinement of need-based technologies by providing continuous feedback on the field problems to the research scientists. Strong and effective interface between researchers and extension workers is ensured through monthly meetings, participation of subject matter specialists in field days and workshops and training camps. During field days and workshops, the researchers come face to face with the farmers and highlight production and protection technology to the farmers and receive the feedback on technology-related difficulties and problems for seeking solutions. Extension wing of the university also organizes monthly interactions with progressive farmers to highlight cutting-edge technologies and their adoption in the state.

To create awareness about the developed technologies and impart education about their benefits, regular workshops and training are organized for the personnel/extension workers of the Department of agriculture. Another important extension activity to disseminate new agriculture technology by the university is holding Kisan Melas (Farmers' Fairs) twice (for kharif and rabi season) at Ludhiana and six times at Regional Stations during each year. More than 5 lakh farmers visit these melas every year, where they personally see the new technologies and interact with the scientists on their economic, natural resource conservation, production and protection implications. The improved seed of newly developed varieties is also sold to the farmers in these fairs. The seed is distributed in small quantities so that a large number of farmers have access to it and develop their own seed for next year crop. Live and intimate links with the growers have paid dividends in the adoption of new technologies at the farmers' fields very quickly. The enterprising and innovative behaviour of farmers has also resulted in quick adoption of new technology.

In addition, extension education also identifies potential stakeholders, fosters partnerships, pools competence and sources from conventional and non-conventional sources to build human capital of rural men and women for their sustainable development. Literature pertaining to farm technologies is compiled and printed and sold at nominal cost to disseminate the information and educate the growers about farm recommendations. The following discussion indicates the degree of adoption of recommended package of production and protection techniques in the case of wheat crop in the Punjab state. These recommendations emerge from rigorous testing of new technologies first at experimental stations and then at farmers' fields in the form of adaptive trials. Two cases on the level of adoption of improved seeds and fertilizer use according to the university's recommendation are discussed here, which are based on a sample survey of 700 farmers in the year 2009–10.

3.7 Variety Coverage Area and Sowing Time

The Punjab Agricultural University has recommended many wheat varieties for cultivation in the State (Table 3.3). The most popular wheat varieties grown are PBW 343 and PBW 502, which occupied 64 and 14 % of the total wheat area in

Table 3.3 List of recommended varieties of wheat in Punjab

Particulars	Name of the variety	Where recommended
Timely sowing	PBW 502, PBW 343, WH 542 and TL 2908	Whole of Punjab
Late sowing	PBW 509	Whole of Punjab except sub-mountainous regions
	PBW 373, TL 1210	Whole of Punjab
Rainfed sowing	PBW 527 and PBW 175	Whole of Punjab
Durum wheat	PDW 274, PDW 291 and PDW 233	Whole of Punjab

Table 3.4 Variety-wise sowing time of wheat on sample farms in Punjab, 2009–10 (area in %)

Variety	End of October	1–15 November	16–30 November	1–15 December	After 15 December	Total	% area under variety
<i>Recommended varieties</i>							
<i>Early sown varieties</i>							
DBW 17	13.12	74.93	11.95	–	–	100.00	1.65
PBW 343	11.81	49.31	30.33	7.70	0.85	100.00	63.64
PBW 502	9.36	61.30	27.81	1.53	–	100.00	14.06
PBW 550	6.23	49.29	40.19	4.29	–	100.00	5.59
WH 542	10.33	55.30	34.37	–	–	100.00	1.86
All early sown	11.05	51.86	30.30	6.17	0.62	100.00	86.80
<i>Late sown varieties</i>							
PBW 373	–	–	54.33	43.97	1.70	100.00	3.39
PBW 509	–	–	45.65	28.26	26.09	100.00	0.44
All late sown	–	–	53.32	42.16	4.52	100.00	3.83
<i>Unrecommended varieties</i>							
HD 2733	–	81.82	18.18	–	–	100.00	0.63
HD 2687	31.94	60.35	5.51	–	–	100.00	4.36
WL 711	–	38.71	61.29	–	–	100.00	1.04
HD 2329	6.57	82.35	11.08	–	–	100.00	2.78
HD 2338	–	40.00	60.00	–	–	100.00	0.10
HD 2851	12.77	61.70	17.02	8.51	–	100.00	0.45
Vikram	–	–	100.00	–	–	100.00	0.01
All unrecommended	17.42	65.68	15.37	1.43	–	100.00	9.37
All varieties	11.22	51.17	29.79	7.10	0.71	100.00	100.00

Note The estimates are based on the sample size of 700 farms spread throughout Punjab

Source PAU (2009a)

2009–10. Around 91 % of the wheat area was under the recommended high yielding varieties of wheat while around 9 % area was under unrecommended wheat varieties (Table 3.4). These unrecommended varieties too are high yielding, developed mostly by the Indian Agricultural Research Institute (IARI) and Wheat Research Institute (WRI), Karnal but are not recommended by PAU for cultivation in the state due to their non-suitability in Punjab due to their vulnerability to diseases and pest attack. Farmers procure their seeds from private seed dealers and cultivate. Even some PAU varieties (WL 711) have also been included in the list of non-recommended varieties because over time these have become more prone to diseases.

Time of planting is another important parameter impacting the crop productivity. The normal sowing time for wheat is from 4th week of October to 4th week of November. Since rice is cultivated on a large proportion of cultivated area, which is harvested by the first week of October, plenty of time is available for timely sowing

of wheat as wheat follows the rice crop in the rice–wheat crop rotation. Thus, around 63 % of wheat area was sown by the first fortnight of October, 2010. Yet, due to limited supply of surface water in southern districts of Punjab some of the wheat area (around 30 %) was planted in the second fortnight of November. Around 11 % of wheat area was planted in the first fortnight of December due to irrigation constraint and cultivation of cotton but a large proportion of this area was under late sown recommended varieties which perform equally good even under late sown conditions.

3.8 Fertilizer Application

As per recommended fertilizer dosage for wheat by PAU, 50 kg of nitrogen, 25 kg of phosphorus and 12.5 kg of potash per acre are applied. This recommendation is based on the crop requirement of different nutrients for the given productivity potential under normal soil health conditions. It is evident from Table 3.5 that the majority of farmers in the state were using higher than recommended dosage of nitrogenous fertilizers in order to realize higher productivity. While use of phosphorus was at the recommended level of 76 % of the sampled farms, about 20 % of them were applying more than the recommended dose of phosphorus on their farms.

Application of potassium K is very less in Punjab soils because its soils are rich in illite minerals supplying potash to plants and hence no application of potash on more than 96 % farms. Zinc and manganese deficiencies have also been shown in soils in the state due to monoculture of wheat–rice and high crop productivity. Yet, its application is not widely prevalent. The inefficient fertilizer application may be attributed to fertilizer subsidies being largely biased towards the nitrogenous fertilizers. More focused extension efforts are required to generate awareness among the farmers on the benefits of balanced fertilizer application in agriculture.

Table 3.5 N, P, K, Zn and Mn application on sample farms for wheat in Punjab, 2009–10 (frequency distribution in percent)

N (kg/acre)	%	P (kg/acre)	%	K (kg/acre)	%	Zinc (kg/acre)	%	Mn (kg/acre)	%
15–25	0.14	Nil	1.00	Nil	95.71	Nil	93.43	Nil	90.86
25–35	0.71	<10	0.14	5–10	0.57	0–1	1.14	1–2	5.00
35–45	2.29	10–20	2.28	10–15	2.00	1–2	0.86	2–3	2.71
45–55	15.43	20–30	76.72	15–20	0.86	2–5	0.71	3–4	0.86
55–65	38.14	30–40	15.29	20–25	–	5–10	1.14	>4	0.57
65–75	35.86	40–50	4.57	25–30	0.43	10–15	2.43	Total	100.00
75–85	6.00	Total	100.00	30–35	0.43	15–20	0.29		
>85	1.43			Total	100.00	Total	100.00		
Total	100.00								

Note The estimates are based on the sample size of 700 farms spread throughout Punjab

Source PAU (2009a)

3.9 Minimum Support Price Policy

The government intervention in foodgrain marketing in India began in a big way in the mid-1960s with a view to encourage widespread adoption of new technology based on high yielding varieties (HYVs) of wheat and rice combined with intensive use of chemical fertilizers under assured irrigation conditions resulting in a comparatively much higher productivity than before. There has been a substantial increase in the MSP (nominal terms) of wheat in the past, with the MSP of wheat increasing from Rs. 117 per quintal during 1980–81 to Rs. 1350 per quintal in 2013–14 (Table 3.6). The highest growth in the MSP was witnessed at 10.72 % per annum during 1990–2000. It owed to the politico-economic situation in the country. During 1980s (Period I), the MSP grew at 4.37 % per annum and it was higher at 6.86 % per annum during 2000–10 and even higher at 7.60 % per annum during 2000–13. The rise in MSP might not have been above the inflation rate during all the years but the extent of rise coupled with effective procurement made it the most remunerative and least risky (production and marketing risk) crop of the winter season.

The role of MSP is to ensure reasonable profits to the producer after covering his cost of production. Ideally, prices in the harvest season should hover around the minimum support prices following an increase (w.r.t. MSP) in the later period due to storage costs and time involved. The positive deviations of farm harvest prices over MSP (FHP > MSP) indicate the effectiveness of MSP for farmers, while negative

Table 3.6 Trends in minimum support price for wheat during 1980–2013 (in Rs/quintal)

Year	MSP	Year	MSP	Year	MSP
1980–81	117	1990–91	215	2000–01	580
1981–82	130	1991–92	225	2001–02	620
1982–83	142	1992–93	275	2002–03	620
1983–84	151	1993–94	330	2003–04	630
1984–85	152	1994–95	350	2004–05	640
1985–86	157	1995–96	360	2005–06	650
1986–87	162	1996–97	380	2006–07	750
1987–88	166	1997–98	475	2007–08	1000
1988–89	173	1998–99	510	2008–09	1080
1989–90	183	1999–00	550	2009–10	1100
				2010–11	1120
				2011–12	1220
				2012–13	1285
				2013–14	1350
<i>Compound growth rate (% per annum)</i>					
Period	CGR	Period	CGR		
1980–1990	4.89	2000–10	6.86		
1990–2000	10.72	2000–13	7.60		

Source GOI (2012)

Table 3.7 Deviations of FHP vis-à-vis MSP of wheat in Punjab state (1980–2010)

State	Period	Negative deviations		Positive deviations	
		Frequency	% difference	Frequency	% difference
Punjab	I(1980–1989)	1	0.70	8	5.00
	II(1990–1999)	0	–	10	6.00
	III(2000–2010)	2	2.39	9	4.89
	IV(1980–2010)	4	3.68	27	5.15

Freq frequency; *% difference* percentage of average positive or negative deviations over average MSP

Source Ali (2009)

deviations (FHP < MSP) reflect the prevalence of distress sale of the produce harming the producer's interest. In Punjab, the farm harvest prices of wheat ruled higher than the MSP in 27 years out of 31 years during 1980–2010 (Table 3.7). On an average, the positive difference between the FHP and MSP was 5.15 % while the negative difference was 3.64 %. These small deviations indicate that the MSP policy for wheat was highly successful in Punjab showing that whatever produce was offered for sale in the market got purchased at MSP or little above. The farmers earned profits. These results reinforce the argument that due to large public procurement of grains, the price policy was more effective in surplus states.

3.10 Determinants of Wheat Production in Punjab

The production choices in Punjab state have undergone significant changes over time. The production of wheat has increased from 5.15 million tonnes in 1970–71 to 17.90 million tonnes in 2011–12. Both, increase in the wheat area and productivity, contributed towards this growth. The area under wheat increased from 2.30 million ha in 1970–71 to 3.51 million ha in 2011–12 and the productivity from 2238 to 5096 kg/ha during the same period. Increase in cropping intensity also helped growth in area under the crop leading to higher production (Table 3.8).

Various factors, price and non-price, are considered to be responsible for growth in yield and production of wheat. Higher relative prices of a commodity in comparison to competing crops result in the transfer of resources under that commodity. On the other hand, increase in irrigated area brings larger area under high-yielding varieties, which are more responsive to the use of chemical fertilizers and consequently, higher yield and higher production are realized. Therefore, apart from better profitability of the crop (derived from combination of price and yield), increase in irrigated area, high use of fertilizers, etc., contributed to growth in wheat production. This section tends to estimate the impact of these factors on area and productivity of wheat in the Punjab state.

For this purpose the data pertaining to the period of 1970–71 to 2011–12 was used. To work out the yield and acreage response, a simultaneous equation model

Table 3.8 Trends in wheat production and other related variables in Punjab

Year	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)	Fert use (kg/ha of GCA)	NIA as % of NAS	Number of electric tubewells (Lakhs)	Cropping intensity (%)
1970–71	2299	5145	2238	38	71	0.91	140
1975–76	2439	5788	2373	47	75	1.46	150
1980–81	2812	7670	2730	113	81	2.80	161
1985–86	3112	10988	3531	153	88	4.41	171
1990–91	3273	12159	3715	163	93	6.00	178
1995–96	3221	12510	3884	164	93	7.25	186
2000–01	3408	15551	4563	165	95	7.88	187
2005–06	3464	14476	4179	214	97	9.05	188
2010–11	3510	16472	4693	242	98	11.42	189
2011–12	3513	17902	5096	243	98	11.57	190

was estimated. The functional form of the simultaneous equation model is given below. The error terms are assumed to be serially independent and identically distributed in such estimation. The equations were identified and subsequently estimated by using the software STATA.

$$A_t = f(A_{t-1}, Y_{t-1}, FHPg_{t-1}, CI)$$

$$CI = f(Ipc_t)$$

$$Y_t = f(Ipc_t, F_{qt})$$

$$F_{qt} = f(F_{pt}, Y_{t-1})$$

where:

A_t Area under wheat ('000 ha) in year t

A_{t-1} Area under wheat ('000 ha) in year $t - 1$

Y_{t-1} Yield of wheat (kg/ha) in year $t - 1$

$FHPg_{t-1}$ Ratio of output price (FHP) of wheat to gram (competing crop) in year $t - 1$

CI_t Cropping intensity in year t

Y_t Yield of wheat (kg/ha) in year t

Ipc_t Percentage of irrigated area in year t

F_{qt} Fertilizer consumption (N + P + K in '000 nutrient tonnes) in wheat in year t

F_{pt} Ratio of price of fertilizer to price of wheat in year t .

Elasticities were calculated to examine the contribution of different factors to wheat acreage and productivity over time. The cropping intensity was found to be the most significant factor influencing acreage under wheat, which in turn was boosted by increase in irrigated area. The elasticity of wheat area with respect to cropping intensity was very high at 0.68 and that of irrigation was about 0.6

Table 3.9 Short-run elasticities of the determinants of area, productivity and related factors of wheat in Punjab

Particular	Area	Cropping intensity	Yield	Fertilizer consumption
FHP (Lag) (SR)	0.04**	–	–	–
Cropping intensity (SR)	0.68**	–	–	–
Yield (Lag) (SR)	–	–	–	1.5***
Percent irrigated area (SR)	–	0.88***	0.72*	–
Fertilizer consumption (SR)	–	–	0.43***	–
Fertilizer–output price ratio	–	–	–	–0.2*

Note The long-run elasticity of FHP (lag) was 0.15 and was significant at 5 % level. *, **, *** mean significance at 10, 5, 1 % levels, respectively

(through cropping intensity). Thus expansion in irrigation helped significantly in raising wheat production in the state through cropping intensity. The impact of price on wheat acreage was significantly positive but was much lower than non-price factors. The short-run price elasticity of wheat area was estimated to be 0.04, while that of long run was 0.15 (Table 3.9). Further, the use of fertilizers and irrigation significantly raised productivity in the state. The respective elasticity coefficients were 0.43 and 0.72. Lower fertilizer prices relative to wheat prices helped in raising fertilizer use and consequently the crop productivity. Yet, the impact of prices was lower (elasticity coefficient of 0.2) than that of irrigation.

3.11 Wheat Revolution and Small Farmers

The foregoing analysis has shown that wheat productivity and production in the state has increased substantially over time due to modern production technology including improved seeds, chemical fertilizers and irrigation complemented by agricultural marketing and price policy, institutional credit and input delivery system. The average income from wheat cultivation to the farmers also rose significantly due to increase in productivity and improvement in input use efficiency. Movements in input and output prices also reflected in the profitability. However, it is imperative to examine whether all farm categories benefitted from this revolution or small farmers' gains were smaller than those of other farmers due to structural constraints in the adoption of new technology because of their poor access to capital and other resources. There was almost no difference in the average productivity of wheat among different farm size categories in the year 2006–07. Small and medium size farms recorded 4.14 and 4.16 t/ha wheat yield while large size farms recorded 4.23 t/ha wheat yield (Table 3.10). This exhibits that technological gains in terms of wheat productivity percolated almost equally to all farm size categories. The use of modern production technology was almost similar on all farms, except the

Table 3.10 Costs and returns from wheat production in Punjab during 1981–82 and 2006–07 (Rs/ha)

Costs/returns	Category of farms		
	Small	Medium	Large
<i>1981–82</i>			
1. Yield (qtl/ha)	28.99	27.91	28.67
2. Gross value of output	4599	4371	4489
3. Cost of cultivation	3509	3273	2849
4. Returns to land and mgt.	1090	1098	1640
5. Cost of production (Rs/qtl)	121	117	99
<i>2006–07</i>			
1. Yield (qtl/ha)	41.39	41.58	42.29
2. Gross value of output	41356	40361	40453
3. Cost of cultivation	16880	17081	15836
4. Returns to land and mgt.	24476	23280	24617
5. Cost of production (Rs/qtl)	408	411	374

differences in the use of large capital equipments (combine harvesters) and labour (Table 3.11). Both sets of farm situations were maximizing their returns by employing more intensively the available resources. For instance, use of labour was high on small farms while machinery was used more intensively on medium and large farms. For other inputs there was hardly any difference. Small farmers therefore had the same level of access to new technology as other farmers had. Similar were the results on average productivity and use of inputs in wheat cultivation in the year 1981–82, which shows that the benefits of new technology were more or less equitably distributed among different farm size categories even in the year 1981–82, when green revolution was getting stabilized (Table 3.12). Yet, profits to the producers (returns to land and management) were higher on large farms as compared to small and medium farms due to size efficiency. However, the differences in profits among different categories got levelled in the year 2006–07. Small farms were using wheat straw to raise gross value of output and to optimally utilize their family labour.

The proportion of large farmers realizing productivity in the range of 4.0–4.5 t/ha was the highest at 58 % while this proportion was around 46 % in small farmers and 45 % in medium farmers in the year 2006–07. The range of highest productivity of 4.5–5.0 t/ha was recorded on medium farms, whose proportion was higher by about 5 % than on small and large farms. Yet, the highest level of productivity was witnessed on small farms though their number was very less, which shows that some small farmers realize very high levels of productivity to compensate for their small holdings (Fig. 3.4).

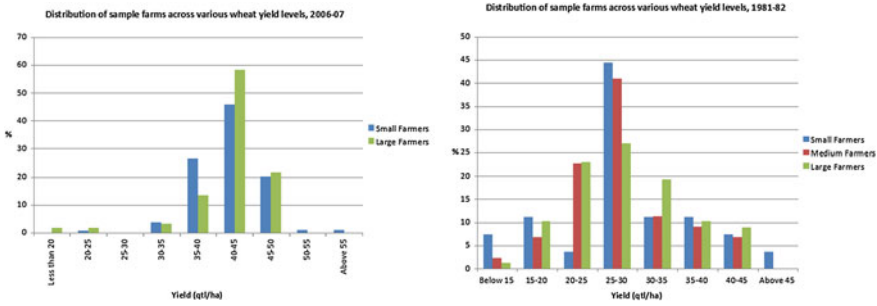


Fig. 3.4 Distribution of farmers across different levels of wheat productivity 1981–82 and 2006–07

3.12 Technical Efficiency of Wheat Across Different Farms

The concept of technical efficiency in a broad sense is used to characterize the utilization of resources on farm. The basic concept is formalized through frontier production function defined as one that maximizes output for given level of inputs. The available literature suggests that stochastic frontier model with a composed error is a more appropriate model to estimate technical efficiency in agriculture production. The technical efficiency of all farms was therefore estimated to study their relative position with respect to the most efficient farm situation(s) by employing this technique. The data set from cost of cultivation scheme for the year 2006–07 was used for measuring the technical efficiency of wheat for different farm size categories. Under this scheme, data is collected from 300 farms spread over the whole state comprising 120 farmers operating less than or equal to 2.0 ha (small farmers), 120 farmers operating area of 2.01–6.0 ha (medium farmers) and 60 farmers operating more than 6.0 ha of land (large farmers). Wheat is grown on all farms in the state. The model is given as under:

$$Y = aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} e^E$$

where:

- Y Wheat production in quintals
- X_1 Human labour in man-hours
- X_2 Tractor use in hours
- X_3 Nitrogen use in kg
- X_4 Phosphorus use in kg
- X_5 Expenditure on plant protection in rupees
- a Intercept
- E Error term

The b_1 – b_5 are the elasticity coefficients and the farm-specific error $E_i = v_i - u_i$. V_i is the symmetric component which permits random error having zero mean associated with random factors and u_i is the one-sided component, which reflects technical inefficiency relative to stochastic frontier.

$$\sigma^2 = \sigma^2 u + \sigma^2 v \text{ and variance ratio } \gamma = \sigma^2 u / \sigma^2 v$$

The γ parameter is estimated, which has value between 0 and 1, where $\gamma = 0$ implies full technical efficiency and a value close to 1 implies that one-sided error term u_i dominates the symmetric error v_i and the shortfall of realized output from the frontier is largely due to technical inefficiency. In the present paper, Frontier 4.1 computer program was used to estimate the maximum likelihood parameter of the stochastic production frontier model, and the indices of the farm-specific technical efficiency (TE) were estimated as:

$$TE_i = \exp(-E[u_i/E_i]), (i = 1, 2, 3, \dots, n) \text{ so that } TE_i \text{ varies from 0 to 1.}$$

The observed variance parameters σ^2 and γ were found to be significantly different from zero, which statistically confirms the differences in technical efficiency in wheat production among different farm situations. The value of γ at 0.54 indicates that more than half of the total variation in wheat production from the frontier was attributed to technical inefficiency (Table 3.13). Therefore, the shortfall of realized output from the frontier was within the control of individual farmer. The mean TE on sample farms in wheat was estimated at 89 %, which indicates that with the given level of input use and technology, there is still 11 % unexploited potential in wheat production in the Punjab state and production can be increased to that extent without any additional input use. TE was also measured for small and other farm categories. It was seen that there were very few farms which operated at less than 80 % technical efficiency and these were almost equally distributed among small (2.53 %), medium (3.34 %) and large (3.33 %) farm categories. Around 45 % of the small holders had the realized output of more than 90 % of the frontier production while such farmers were 49 % in medium farm size category and 57 % in the large farm size category. In brief, most of the farmers in each size-category were able to reach 85–95 % of the frontier levels of productivity, reflecting that the farmers were highly efficient. The realization of higher technical efficiency can be attributed to a highly effective extension system in the state, access and use of improved inputs such as seeds, fertilizers and agrochemicals (Fig. 3.5).

3.13 Conclusion and Policy Implications

The productivity and production of foodgrains at the national level too is largely dependent upon irrigation in combination with high yielding varieties and use of fertilizers. The growth/stagnation in the production of wheat is therefore determined

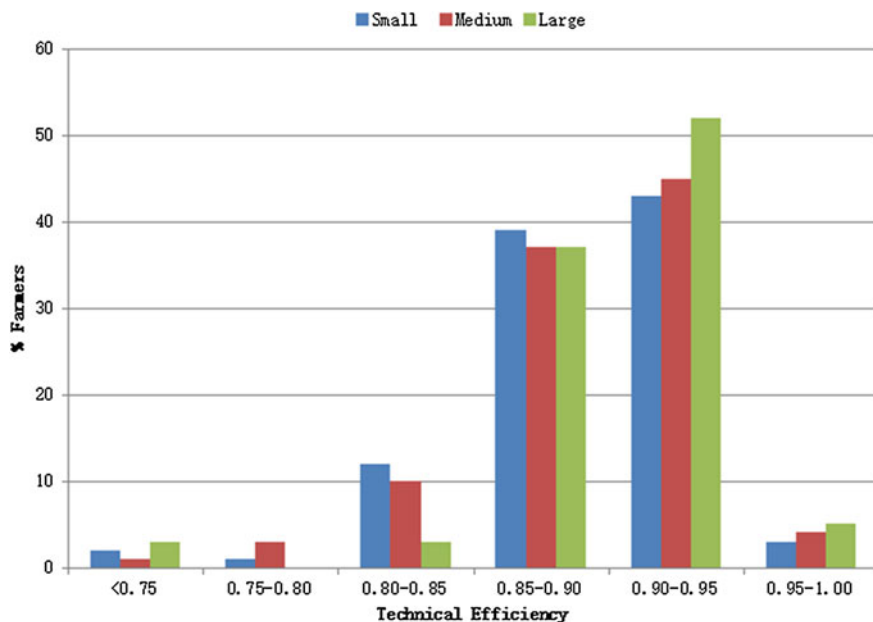


Fig. 3.5 Distribution of sample farms by technical efficiency levels, 2006–07

by the availability of irrigation water, fertilizer-responsive HYVs of crops, its price in relation with input prices and availability of credit for purchasing fertilizers and other inputs. The growth pattern of wheat output in relation to these determinants in India was similar during the last three and a half decades. The adoption of HYVs of wheat on irrigated areas along with higher use of fertilizers turned out to be the prime mover for its production. The prices of fertilizers in relation to wheat prices along with institutional credit facilitated this process. After registering significant growth in 1970s and 1980s, the growth slowed down and almost stopped after mid-1990s. When the area under irrigation stagnated due to fall in public investments in irrigation, the whole process of growth in wheat production got blunted and ultimately stagnation set in threatening the food security of the country.

The foregoing estimates on elasticities derived from the three and a half decades of experience in wheat production in India can be used to build the scenario of its 4 % growth. It is assumed that the net irrigated area grows at the rate of 1.5 % per annum, which roughly comes to one million hectare. The past data shows that 40 % of additional irrigated area goes under wheat due to its relative technology and price advantage compared to competing crops, which comes to 3.32 % increase in wheat irrigated area. Taking the elasticity of area under HYVs of wheat to irrigated area at 1.12, the increase in wheat area under HYVs will be 3.59 %. Since the elasticity of

wheat production to area under HYVs is 0.73, the production is expected to increase by 2.6 % due to rise in area under HYVs. Similarly, fertilizer use is very responsive to coverage of area under HYVs, which will go up by about 4.85 % on the basis of 1.35 elasticity coefficient. Higher use of fertilizers by 5.2 % will further enhance wheat production by 1.16 %. Further, as experienced in the past, the fertilizer–wheat price ratio and institutional agricultural credit supply are assumed to be maintained at current level. Therefore, annual increase in irrigated area by one million ha will significantly push the wheat production to ensure food security of the country in the long run.

Irrigation will act as a ‘trigger’ for growth and will lead to a larger area under high yielding varieties and greater demand for fertilizers under the supportive institutional backup in price policy and credit. Irrigation investments therefore can bring the agriculture sector out of morass of stagnation. To start with, irrigation investments may be made in the most potential unirrigated areas, the rest of the components of the strategy will automatically start working and the agriculture sector will get the required momentum and move on to a higher growth path. The net sown area is less than 10 % in Jharkhand and less than about 30 % in Orissa and Chhattisgarh and Madhya Pradesh. Similarly, a large chunk of area in Bihar, West Bengal and eastern Uttar Pradesh is unirrigated where the scope of irrigation expansion is immense. The average productivity of wheat in these areas is less than 2 t/ha, which can be raised by irrigation. The All India Coordinated Research Project on Wheat has indicated that the difference in productivity between front-line demonstrations and farmers’ fields is almost 52 %, which needs to be bridged by targeted extension activities to encourage adoption of modern technologies including high yielding seeds, fertilizers and other inputs. The policy should therefore lay emphasis on the development of irrigation potential in these areas on priority. Secondly, the already created irrigation potential must be exploited fully through the maintenance of old irrigation infrastructure. While there is a strong case for expanding the irrigation potential, it is also emphasized that the focus should also be there to improve the water use efficiency in agriculture. Apart from that, the cropping patterns should be planned as per the natural resource endowments of the regions (especially the groundwater) and should not lead to the over-exploitation of the resources in the long run. The pricing policy (not only for output but also for inputs such as electricity, irrigation water and fertilizers) should also focus to encourage the optimal water use in the scenario of enhanced irrigation potential.

Appendix

See Tables [3.11](#), [3.12](#) and [3.13](#).

Table 3.11 Pattern of input use in wheat production in Punjab during 2006–07

Input	Unit	Category of farms		
		Small	Medium	Large
1. Human labour	Man hours			
• Owned		118.25	73.14	51.11
• Hired		176.42	120.90	87.13
• Total		294.67	194.04	138.23
2. Animal labour	Hours	2.59	0.66	0.54
3. Tractor use	Hours			
• Owned		1.72	10.64	12.80
• Hired		13.47	5.24	2.74
• Total		15.19	15.88	15.54
4. Combine harvester use	Hours	0.64	1.09	1.39
5. Seed value	Rs	1086.96	1090.46	1038.32
6. FYM				
• Quantity	qtl	9.99	13.41	1.49
• Value	Rs	53.93	75.92	8.55
7. Fertilizer nutrients				
• N	kg	158.51	160.77	161.47
• P	kg	65.72	64.23	65.94
• K	kg	0.81	0.75	0.66
• Total value	Rs	2730.09	2729.35	2761.83
8. Insecticides and fungicides	Rs	146.67	156.41	160.91
9. Weedicides	Rs	798.58	776.06	806.53
Main product	qtl	41.39	41.58	42.29
Av. farm size	Ha	1.32	3.98	8.60
% area under wheat (%)	% of GCA	40.01	40.94	38.92

Table 3.12 Pattern of input use in wheat production in Punjab during 1981–82

Input	Unit	Category of farms		
		Small	Medium	Large
1. Human labour	Man hours			
• Owned		319.74	236.36	137.40
• Hired		149.35	189.86	206.62
• Total		469.09	426.22	344.02
2. Animal labour	Hours	62.48	43.54	10.03
3. Tractor use	Hours			
• Owned		3.01	6.31	9.83
• Hired		1.89	1.76	0.29
• Total		4.90	8.07	10.12

(continued)

Table 3.12 (continued)

Input	Unit	Category of farms		
	Per ha	Small	Medium	Large
4. Combine harvester use	Hours	–	0.07	0.16
5. Seed				
• Quantity	kg	153.31	173.46	163.48
• Value	Rs			
6. FYM				
• Quantity	kg	6.25	9.21	2.30
• Value	Rs	6.25	11.07	2.68
7. Fertilizer nutrients				
• N	kg	102.21	108.09	105.95
• P	kg	48.11	45.94	47.85
• K	kg	5.66	8.26	8.05
• NPK	kg	150.32	162.29	161.85
• Total value	Rs	1089.04	868.05	872.13
8. Insecticides and fungicides	Rs	19.07	43.75	92.02
9. Weedicides	Rs	1092.25	931.02	773.33
10. Main product	Qtl	28.99	27.91	28.67
11. Average farm size	Ha	2.20	4.69	10.48
12. % area under wheat	% of NAS	70.00	76.33	71.56

Table 3.13 Maximum likelihood estimates of stochastic frontier production function for wheat in Punjab, 2006–07

Particular	Coefficient	Standard-error	<i>t</i> -ratio
Intercept	–0.6686	0.1240	–5.3926
Human labour (hours)	0.0413	0.0189	2.1877
Tractor labour (hours)	0.1689	0.0405	4.1749
N-kg	0.6138	0.0430	14.2806
P-kg	0.1593	0.0219	7.2790
Chemicals (Rs)	0.0100	0.0082	1.2289
σ^2	0.0405	0.0073	5.5519
γ	0.5444	0.1530	3.5569
Log-likelihood function	118.1320		

Note All values are significant at 5 % level. Log-likelihood is significant at 10 % level

References

- Ali SZ (2009) Effectiveness of price policy for foodgrains in India with special reference to Punjab State. Unpublished thesis. Punjab Agricultural University, Ludhiana
- Chand R (2005) Exploring possibilities of achieving four percent growth rate in Indian agriculture. Working paper, National Centre for Agricultural Economics and Policy Research. New Delhi
- GOI (2012) Agricultural statistics at a glance. Ministry of Agriculture, Government of India, New Delhi
- PAU (2009a) Prospects of wheat crop: 2009–10. Department of Economics and Sociology, PAU, Ludhiana
- PAU (2009b) Status report on PAU. Punjab Agricultural University, Ludhiana
- Sidhu RS, Gill SS (2006) Agricultural credit and indebtedness in India: some issues, keynote paper. *Indian J Agric Econ* 61:11–35
- Sidhu RS, Bhullar AS, Joshi AS (2005) Income, employment and productivity growth in the farming sector of Punjab: some issues. *J Indian Sch Polit Econ* 17:59–72