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Full Length Research Paper

Genetic diversity for sustainability of rice crop in Indian Punjab and its implications

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The varietal diversity in rice crop in Indian Punjab has been increasing at a fast rate due to variable soil and climatic conditions and variable objective functions of the farmers. In spite of the fact that productivity of rice increased over time, as a result of improvement in technology and its fast adoption, the declining resource base, particularly water, soil health and pest resistance, the genetic diversity of rice crop has been able to sustain the yield improvement as compared to wheat crop which witnessed a reverse trend of decline in genetic diversity.

Key words: Indian Punjab, genetic diversity, sustainability, green revolution, basmati rice.

INTRODUCTION

Due to highly diverse agro-climatic conditions in India and the high importance of rice in the food basket of the consumers, the crop is grown under varied conditions and thus has high degree of genetic diversity. The M. S. Swaminathan Research Foundation in India claims that India alone has 100,000 traditional varieties still in use by the farmers around the country and another 300,000 that have become extinct (Hamilton, 2006). Historically, evidence exists about rice being a staple food crop of Indian Punjab as early as 2000 - 1500 BC due to which landraces cultivated in the state possessed good cooking and eating qualities, most of which belonged to basmati rice (Sidhu and Singh, 2000). Due to various reasons, later the emphasis shifted from rice to wheat in dietary pattern and subsequently in production pattern too. Therefore, rice ceased to be an important crop of Punjab state till the initiation of 'Green Revolution' in mid-sixties when it again stormed in crop pattern of the state, now covering about two-thirds of the cultivated area of the state.

The organized efforts of genetic improvement of rice in Punjab were started in the plains in 1926 and in hills in 1936. Till 1940, a number of varieties such as Jhona 349, Mushkan 7, Mushkan 41, Basmati 370, Sathra 278, Palman Suffaid 246 and Mahlar 346 with typical characteristics of high yielding, resistant to lodging, tolerant to salts, good cooking and eating qualities were released. Partition of the country in 1947 and political reorganization of Punjab state in 1966 gave serious jolts to rice improvement work which was ultimately shifted to Kapurthala Regional Centre of Punjab Agricultural University.

The remarkable progress of food grain production (mainly wheat and rice) in the post-green revolution period in Punjab was a mixed blessing. It was possible to generate huge surpluses apart from meeting the requirements of the fast growing population of the country and improvement in the economic lot of farmers. The sad part of it was the high rate of resource depletion, particularly water and soil health, increasing pest resistance and air pollution due to large scale burning of crop residue and diminishing ecological bio-diversity apart from almost stagnation of yield and thus overall slowing pace of farm economy. The average yield of rice was only 1009 kg/ha in 1960 - 1961 but touched a level of 3715 kg/ha in 2006 - 2007 (Table 1). The area under the crop was hardly 227 thousand hectares in 1960 – 1961 which went up to 2611 thousand hectares in 2000 - 2001 and reached a plateau thereafter. On the other hand, as a result of shift in crop pattern in favour of rice, a number of marginal crops such as tobacco, pulses, oilseeds, millets, sorghum, cluster beans, maize, sun hemp which had significant area have almost vanished from the state agriculture scene. A glance of compound growth rates (CGRs) would show that the average yield increased at 5.29% in 1970's, 1.29% in 1980's but it almost stagnated in 1990's. However, during the past five years, it has somewhat revived due to favourable climatic conditions. The corresponding CGRs in area worked out to 13.36, 5.43, 2.51 and -0.20%, respectively (Table 1).

Table 1. Area, average yield and production of rice in Punjab.

Year	Rice		
	Area (000 ha)	Average yield (Kg/ha)	Production (000 tonnes)
1960-61	227	1009	229
1970-71	390	1765	668
1980-81	1183	2733	3233
1990-91	2015	3229	6506
2000-01	2611	3506	9154
2006-07	2425	3715	9010
Compound growth rates (%)			
1970-71 to 1979-80	13.36	5.29	18.65
1980-81 to 1989-90	5.43	1.29	6.72
1990-91 to 1999-00	2.51	0.02	2.53
2000-01 to 2006-07	-0.20	1.65	1.45

Statistical abstracts of Punjab.

The production of rice in Punjab was 9 million tones in 2006 - 2007 from the area of 2.4 million hectares under the crop. The average yield in terms of rice worked out to 3715 kg/ha. Out of the total rice area, basmati strains covered 122 thousand hectares thus accounting for 5.03% of total area under rice crop. The comparative average yield of basmati rice was almost half of that of non-basmati and was estimated at 2019 kg/ha (Singh, 2007).

The slower rates of variety change dampened the productivity in Punjab and also offset the positive impact on diversifying genetic base through plant breeding (Smale, 2008). The varietal and genetic scenario of wheat and rice crops has undergone metamorphosis in Punjab. Guided by economic forces, a few high yielding varieties quickly replaced most of the low yielding ones. Of course, susceptibility to pests, diseases and lodging and quality parameters do get significant weight age in the choice of suitable varieties. This paper was attempted with the following specific objectives:

(1) To study changes in varietal and genetic diversification of rice crop in Punjab agriculture.
(2) To bring out the impact of such diversification on production.
(3) To suggest policy implications of such developments.

METHODOLOGY

Although, it is well understood that the genetic diversity is not congruent to varietal diversity but by and large, the number of parents in every successively introduced variety are increasing with the genetic improvement of the rice crop in the state (Sidhu and Singh, 2004). Due to non-availability of information about parentage in back tracing of varieties, it was presumed that increase in the number of varieties and thus parentage makes the genetic base much more diverse having implications on sustainability of the crop.

For making production estimates, a survey on 'Prospects of rice crop in Punjab' was carried out by Punjab Agricultural University every year by taking a sample of about 1000 farmers (Singh, 2008). The District Farm Management Specialists were entrusted with the job of collecting data regarding shift in area, sowing time, seed rate, area under different varieties etc. The data on varietal scenario have been used for this analysis. The Theil Entropy Index (E) (Shorrocks, 1984) has been used for measuring the diversification as under:

$$E = \sum_{i=1}^{n} \{Pi \log (1/Pi)\}$$

Where Pi = Proportion of area under ith variety, N = Number of varieties raised by farmers.

Therefore, the value of E should vary from 0 to log n. The secondary data (Economic & Statistical Organization ESO, Punjab (2008), various issues) were also used to construct series of probable explanatory variables, explaining the yield of rice crop in the regression analysis.

RESULTS AND DISCUSSION

Varietal scenario

There was in general, increase in the number of rice varieties adopted by the farmers over time. In 1982 - 1983, only 7 varieties with dominance of PR 106 were in cultivation. The number gradually swelled to 15 in 1999 - 2000. As more and more of genetic material, recommended or unrecommended, started pouring in the area, varietal diversification increased. The varietal diversification index measured by Theil's Entropy index was 0.3591 in 1982 - 1983 which increased to 0.6246 in 1992 - 1993, 0.8008 in 2002 - 2003 and 0.8974 in 2007 - 2008 (Table 3 and Figure 1). In early 1980s, PR106, Jaya and IR8 were the dominant varieties, potentials of which

Table 3. Varietal diversification of rice in Punjab (Area as % of total area under rice crop).

Year	PR106	Indrasan	PR108	Pusa44	IR8/Jaya	PR111	PR110	PR103	PR109	Satha	Basmati	PR113	PR114	PR115	PR116	PR118	Sharbati	Others	DI
1982-1983	71.2				22.0			1.7			3.6							1.5	0.3591
1983-1984	73.4				17.3			2.6			5.0							1.7	0.3667
1984-1985	67.0				24.4			4.1			3.6							0.9	0.3933
1985-1986	60.2	1.7			30.7			1.0			3.2							3.2	0.4359
1986-1987	48.7	5.4	6.5		28.7			0.9	2.8		4.8							2.2	0.6150
1987-1988	36.5	7.5	15.9		19.3			1.3	14.9		3.8							0.8	0.7275
1988-1989	53.8	7.7	8.6		17.1			4.1	1.4		5.5							1.8	0.6369
1989-1990	58.4	6.8	7.3		17.1			3.1	0.2		4.9							2.2	0.5828
1990-1991	55.3	7.5	3.6	11.3	13.3			3.1	0		2.8							3.1	0.6392
1991-1992	62.1	6.6	3.0	9.6	10.5		0.1	2.7	0.2	0.6	2.8							1.8	0.5915
1992-1993	61.4	5.5	3.1	9.4	8.8		1.7	3.4	0.1	2.3	3.4							0.9	0.6246
1993-1994	52.1	6.9	4.3	17.6	8.8		2.1	3.6		1.0	2.7							0.9	0.6801
1994-1995	48.2	6.4	7.9	15.7	10.9	3.2	2.0	1.9		0	2.5							1.3	0.7265
1995-1996	40.7	5.6	7.5	17.3	15.1	8.1	2.2	0.6		0	1.9							1	0.7601
1996-1997	33.2	5.2	8.2	20.4	12.5	14.8	1.7	1.3	0.1	0.4	1.6							0.6	0.8006
1997-1998	23.2	4.5	7.5	27.8	10.0	21.6	1.0	2.0	0.2	0.4	1.6							0.2	0.7936
1998-1999	19.1	2.2	2.5	30.5	9.9	22.0	0.3	1.2		0.8	2.5	6.5						2.5	0.8199
1999-2000	20.3	2.0	2.3	26.9	7.7	10.7	0.3	0.7		2.2	2.4	15.3	5.0					4.2	0.9008
2000-2001	8.4	0.0	1.6	10.3	5.2	5.8		0.2		2.7	1.5	16.0	37.4	1.2	4.2			5.5	0.8716
2001-2002	3.3	3.8	2.4	23.4	2.3	4.9				1.1	3.3	2.5	11.0	0.4	37.3			4.3	0.8352
2002-2003	3.1	4.9	2.0	20.8	1.2	4.8				1.1	3.9	2.2	8.2	0.2	43.1	0.1		4.4	0.8008
2003-2004	2.2	5.1	2.4	17.6	0.6	4.6				0.6	12.7	2.0	4.2	0.1	40.0	2.8		5.1	0.8394
2004-2005	2.3	1.2	2.2	30.1	0.3	6.5				1.8	7.1	3.3	3.3	0.3	25.3	7.6	2.4	6.3	0.9078
2005-2006	1.8	1.1	2.3	34.5	0.4	9.2		0.1		3.5	8.9	6.5	3.2	0.1	13.5	8.4	4.9	1.6	0.9311
2006-2007	1.9	0.9	0.7	36.7	0	8.5				2.6	3.8	7.7	6.7	0.2	7.5	8.6	5.0	9.2	0.9183
2007-2008	1.5	0.5	0.3	33.0	0	7.4				1.3	3.8	6.4	5.3	0.5	9.3	8.6	3.5	18.6	0.8974

DI=Diversification index.

dampened over time. These were replaced by some improved varieties, many of which also could not stand the test of time. Some of the new varieties were recommended by Punjab Agricultural University and the others endeavored by the farmers themselves by subsequent testing on their fields. Pusa 44 and Indrasan are the glaring cases which are not recommended for the state owing to its long duration, high water requirements and susceptibility to bacterial leaf blight but due to higher yield and better quality, these have been quite popular with the farmers and have still been occupying a significant part of the rice area in the state (Table 3). Basmati varieties have been occupying 4 - 6% of the total area under rice in the state. The traditional basmati belt of Punjab preferred basmati 370 having long aromatic grains and rice straw as preferred livestock feed. Pakistani basmati was successfully tried by the farmers of the area because it had higher yield but lacked

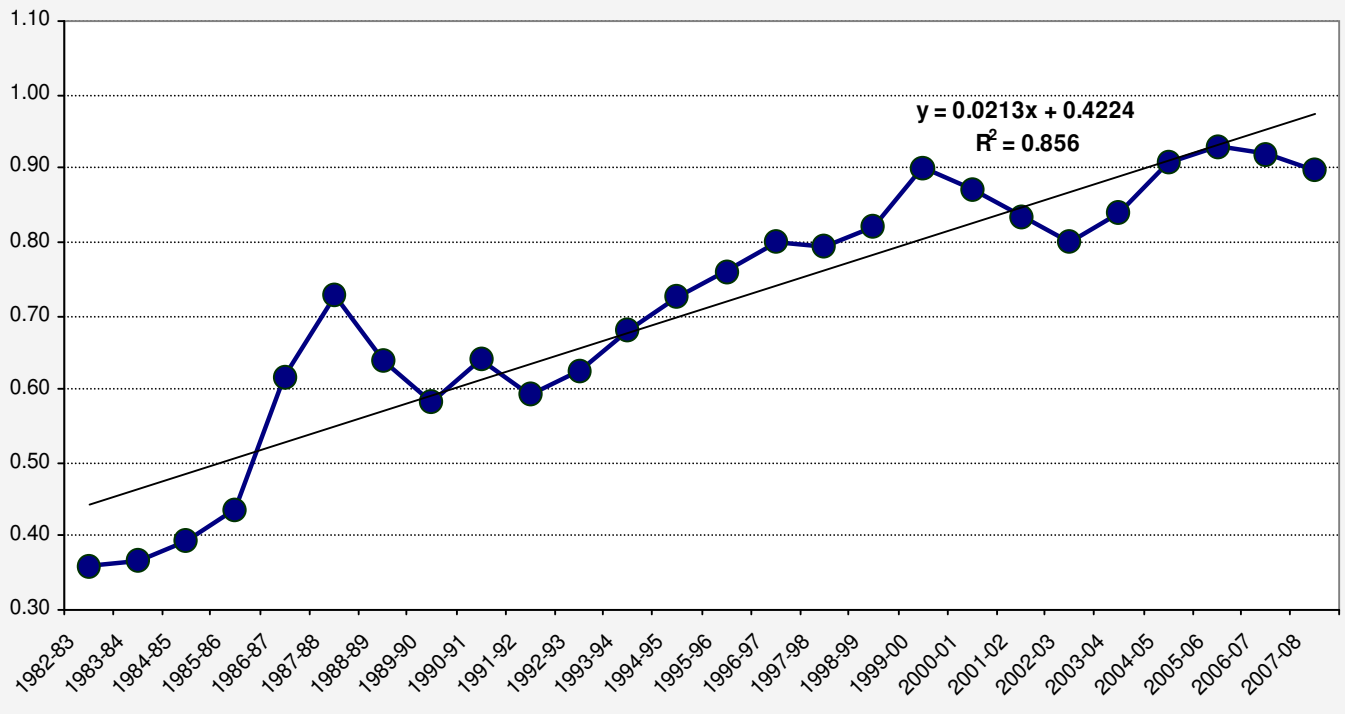

Figure 1. Diversification index of rice in Punjab.

Table 2. Estimated production function with varietal diversity.

Variable	Coefficient	t-value
Intercept	3436.24**	
Varietal diversity	2.6995*	2.2389
Rainfall	-0.5023	-1.0420
Chemical fertilizer use	8.5779*	2.1529
Zinc sulphate	0.0277*	2.1273

R^2 = 0.6899, *Significant at 0.05 probability level; ** Significant at 0.01 probability level.

fragrance. Trade followed the practice of mixing it with Basmati 370. Later on Basmati 370 and Pakistani Basmati were crossed resulting in introduction of Basmati 386. Recently, Sarbati and Basmati 1121 have also been introduced by the farmers but not recommended by the research system due to their susceptibility to Foot Rot and Bacterial Leaf Blight. The basmati strains are considered relatively more environmentally friendly as these are transplanted late and their water requirement goes down sizably. Currently, there is a wide range of rice varieties grown in Punjab. The range varies from short duration of 65 days (Satha) to 165 days (Pusa 44) in the field, apart from 30-45 days in nursery. The quality and thus price based variations can be seen from coarse (IR8) to best quality basmati rice (Basmati 386). The varieties have varying degrees of susceptibility to pests and diseases, lodging and other biotic and abiotic stresses. Similarly, early and late sown varieties are also adopted by the farmers depending upon the farm situations.

Therefore based on different farm situations with respect to crop rotation, market conditions, suitability of soil and water resources, past experience etc., the rice growers have wider choice of seeds. The breeders do not favour it but the farmers have tailored genetic system to suit their requirements.

Impact of varietal diversity

The results of linear regression analysis are presented in Table 2. It may be seen from this table that natural factors such as rainfall did not exert significant effect on yield of rice crop in Punjab because almost all the entire

cultivated area, particularly of rice crop had assured surface and subsurface groundwater supply system. The significant effects of fertilizers and zinc indicated that replenishment of soil fertility with use of chemical fertilizers and even micro-nutrients such as zinc, manganese and ferrous is becoming important with continuously taking rice crop year after year (Appendix 1). The significance of varietal diversity for improving crop yield is sufficient indication of its importance for sustaining the rice crop in the state.

Therefore, it can be inferred that cultivation of rice crop started with the onset of 'green revolution' in mid sixties and is now occupying a prominent place in the crop pattern and research system of the state and food security of the country. The varietal diversity in rice crop in Indian Punjab has been increasing at a fast rate, possibly due to variable agro-climatic conditions under which the crop is grown and variable objective functions of the farmers. In spite of the fact that productivity of rice increased over time as a result of improvement in technology and its fast adoption, the declining resource base, particularly water, soil health and pest resistance, the genetic diversity of rice crop has been able to sustain the yield improvement as compared to wheat crop which witnessed a reverse trend of decline in genetic diversity in the state (Smale, 2008).

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Appendix 1. A glance of important parameters of Punjab agriculture.

Year	Zinc sulphate (tonnes)	Ferrous sulphate (tonnes)	Manganese sulphate (tonnes)	Fertilizers with major nutrients (000 tonnes)	Pesticides (TGM) (tonnes)	Area irrigated (%)
1980-1981	5042	0	0	762	3200	86
1990-1991	9018	378	0	1220	6500	94
2000-2001	23340	1360	80	1407	7005	97
2005-2006	32000	3500	568	1686	6020	97
2006-2007	NA	NA	NA	1717	6000	97

NA=Not available, Statistical abstracts of Punjab, 2008 and agricultural statistics of Punjab, 2009.