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Effect of chiselling, green-manuring and planting methods on productivity and profitability of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted at Karnal during 2000-01 to 2003-04 to assess the effect of alternate-year chiselling (after rice crop) in rice-wheat system. Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.) - greengram (*Phaseolus radiatus*), rice - wheat - *Sesbania aculeata* and rice-wheat were tried on flat- and bed-planting systems for improving the productivity of rice-wheat system. Combined analysis showed that alternate year chiselling produced at par rice and wheat yields and rice-equivalent yield compared with non-chiselled one. Green-manuring saved 25% N for rice crop and recorded higher rice equivalent yield (15.30 to 15.41 t/ha) compared with rice-wheat system (15.03 t/ha) under flat planting. Bed-planting of wheat recorded 6.5% lower grain yield than flat-planting system. Growing green manure crops improved the land-use efficiency and decreased the production efficiency due to higher duration. Taking green-manure crops increased the cost of cultivation (7.7%), and hence decreased the net returns and benefit : cost ratio compared with the conventional rice-wheat system. Introduction of greengram either under flat or bed planting and *Sesbania aculeata* incorporation under flat planting increased the organic C content by 13.2% than rice-wheat system. The chiselled plot gave 17-23% higher cumulative infiltration at later stages than non-chiselled plot. It was concluded that wheat on bed produces slightly lower grain yield, chiselling increases infiltration rate and green-manuring saves N and improves the organic C content of the soil.

Key words: Economics, Green-manuring, Organic carbon, Rice-wheat, Rice-equivalent yield, Yield

Since the inception of green revolution in mid-1960s, India has made tremendous progress in area, production and productivity of wheat. Total production increased over six-fold from 12 million tonnes to 75 million tonnes in 2007. Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L. emend. Fiori & Paol.) is the most important crop sequence, occupying 10.3 million ha area in India (Timsina and Connor, 2001). In Haryana approximately half a million ha area is under rice-wheat system. The contribution of rice and wheat to the national foodgrain production has increased from 52% during 1950s to 77.7% during 2006-07. About 23 and 40% of the total rice and wheat area respectively and 25.7% production is represented by rice-wheat system alone, which requires contrasting edaphic conditions. Rice is grown under puddled condition, which results in formation of hard pan below the surface (Sharma and Datta, 1986; Sharma *et al.*, 2003). Studies have shown that formation of hard pan is more prone in continuous rice-wheat than maize-wheat system (Boparai *et al.*, 1992). Continuing rice-wheat system by growing green-manure crop or greengram after wheat might be helpful in increasing the soil and crop productivity. In this endeavour economics will play an important role in the adoption of a cropping system. Farmers always strive for earning maximum net returns per unit area with minimum risk. Therefore, a need was felt to evaluate green-manuring options under different planting methods to maximize production, land use and economic efficiencies of the system with the existing or improved soil fertility.

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MATERIALS AND METHODS

A field experiment was conducted for four consecutive years from 2000-01 to 2003-04 at Directorate of Wheat Research, Karnal (latitude 29°43' N, longitude 76° 58' E and altitude 245 m above mean sea level). The experimental soil was sandy clay-loam in texture (22% clay), with 7.8 pH low in organic C (0.37%) and available N (145 kg/ha), and medium in available P (17.2 kg/ha) and available K (155 kg/ha) content. The soil samples were analysed at the beginning of the experiment and after completion of four cropping cycles for organic C and pH.

The experiment consisted of two main plots (alternate-year chiselling and no chiselling) and six subplot treatments, viz. rice – wheat - greengram, rice - wheat -

Sesbania aculeata and rice – wheat on flat and bed planting systems, with three replications in split-plot design. The size of bed was 70 cm, where top of bed was 40 cm and furrow 30 cm. Three lines of wheat were sown on top of bed with the help of DWR bed planter. The plot size was 28 m^2. Rice and wheat varieties used were 'IR 64' and 'PBW 343', respectively with recommended packages of practices. Fertilizers @ 150 kg N +26.2 kg P + 33.3 kg K/ha were applied both in rice and wheat. Rice crop preceded by green-manuring of *Sesbania aculeata* or greengram received 25% lesser N than other treatments. The chiselling treatment (70 cm deep) was imposed before the field preparation for wheat sowing in the second and fourth years of the study.

The cost of cultivation was calculated by taking into account the prevailing prices of inputs. The returns were calculated by using the minimum support price of crops and prevailing market price of wheat straw. The minimum support price (per kg) used for economic calculation for rice and wheat was: Rs 5.40 and Rs 6.10/kg for 2000-01, Rs 5.60 and Rs 6.20/kg for 2001-02, and Rs 5.80 and Rs 6.30/kg for 2002-03 and 2003-04, respectively. Different crop sequences were compared by converting the yield of all the crops into rice-equivalent on price basis. The intensification in temporal dimension was measured in terms of land use efficiency by taking total duration of crops in a sequence divided by 365 days. Production efficiency was calculated as rice equivalent yield in a crop sequence divided by duration of sequence (Tomar and Tiwari, 1990). Rice and wheat yields and rice-equivalent yield were analysed on yearly basis and combined over the years for comparison of treatments.

RESULTS AND DISCUSSION

Crop productivity

Alternate-year chiselling showed an edge in rice and wheat yields over non-chiselling, though non-significant, except for the rice yield in 2003-04, which was significantly higher in chiselled plots (7.08 t/ha) compared with non-chiselled plot (6.65 t/ha). In pooled analysis too, the rice and wheat yields were non-significant in chiselled and non-chiselled treatments (Table 1). The effect of various crop sequences was significant except for rice yield in 2000-01 and 2001-02 and wheat in 2003-04. The pooled analysis showed that the incorporation of greengram or *Sesbania aculeata* produced higher rice yield than rice-wheat (flat) planting. This was achieved even by 25% lesser N application for the rice crop preceded by green-manuring. The effect of green-manuring on wheat crop was not conspicuous. Though wheat planted on bed recorded significantly lower grain yield (5.28 t/ha) than flat (5.63 t/ha)-planted crop. There was year-to-year variation in the yield of rice and wheat. Maximum rice yield (8.73-9.11 t/ha) was recorded during 2001-02, but lowest (6.37 t/ha) during 2003-04. On the contrary, wheat yield was more stable than rice in different years. Thus, more effort is needed to sustain the productivity of rice than of wheat.

Alternate-year chiselling did not produce significantly higher rice-equivalent yield than non-chiselled plots (Table 2). In pooled analysis maximum rice-equivalent yield (15.3-15.4 t/ha) was obtained with flat plating of rice – wheat - *Sesbania aculeata or* greengram, which was significantly higher than of all other crop sequences. This showed that flat planting is the best option for green-manuring of either *Sesbania aculeata* or greengram com-

Table 1. Yearly and pooled analysis of rice and wheat grain yield (t/ha) under different treatments

Treatment	2000-01		2001-02		2002-03		2003-04		Pooled	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Chiselling										
With chiselling	6.97	6.14	8.97	5.89	8.12	5.69	7.07	4.71	7.78	*5.61*
Without chiselling	6.88	5.88	8.76	5.88	8.00	5.38	6.65	4.53	7.57	5.42
SEm±	0.11	0.05	0.14	0.10	0.05	0.16	0.07	0.09	0.08	0.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.39	NS	NS	NS
Crop sequences and planting methods										
Rice – wheat (bed)	6.88	5.70	8.76	5.47	8.56	5.29	6.51	4.64	7.67	5.28
Rice – wheat – greengram (bed)	6.83	5.98	9.11	5.71	7.86	5.54	7.10	4.59	7.73	5.46
Rice – wheat – *dhaincha* (bed)	7.03	5.79	9.06	5.51	7.64	5.33	6.77	4.48	7.63	5.28
Rice – wheat (flat)	6.90	6.13	8.66	6.04	8.21	5.65	6.37	4.69	7.54	5.63
Rice – wheat - greengram (flat)	7.00	6.17	8.88	6.17	7.95	5.69	7.34	4.61	7.79	5.66
Rice – wheat - *dhaincha* (flat)	6.90	6.27	8.73	6.42	8.14	5.74	7.07	4.71	7.71	5.79
SEm±	0.12	0.09	0.26	0.10	0.14	0.12	0.13	0.27	0.08	0.07
CD (P=0.05)	NS	0.28	NS	0.31	0.41	0.36	0.37	NS	0.23	0.22

pared with bed planting. This supports the observation of Chauhan *et al.* (2001), who also found that green-manuring treatments improved the rice-equivalent yield. The lowest rice-equivalent yield (14.65 t/ha) was recorded in rice–wheat (bed) planting systems. Interaction between chiselling and cropping system was non-significant.

Land use and production efficiency

Land use and production efficiencies were calculated for different crop rotations. Green-manuring of *Sesbania aculeata* or greengram improved the land-use efficiency up to 87.39% compared with no green-manuring treatments (72%). However, production efficiency decreased after green-manuring treatments (45.91 - 48.30 kg/ha/day) compared with non-green manured plots (53.70 - 57.13 kg/ha/day). This decrease in production efficiency in green-manured treatments was due to longer duration of the rotation.

Economics

Pooled analysis showed that chiselled plots recorded higher net returns than non-chiselled plots. Net returns were maximum in rice-wheat system where wheat was planted on flat-bed. The green-manuring options of greengram or *Sesbania aculeata* on bed and greengram on flat planting reduced the net returns significantly. The incorporation of *Sesbania aculeata* with conventional rice-wheat system showed at par net returns. This led to lower benefit : cost ratio in green-manured plots than in non green-manured treatments (Table 2). This finding is in agreement with the observation of Chauhan *et al.* (2001). This is the reason for the non-adoption of green-manuring with *Sesbania aculeata* under rice-wheat system. Therefore, dual-purpose short-duration greengram varieties are more profitable than sole green-manuring options.

Soil fertility

Raising of greengram under flat or bed plating methods and *Sesbania aculeata* on flat planting significantly improved the organic C content and decreased the pH after 4 years of the study (Table 2). Introduction of greengram either under flat or bed planting and *Sesbania aculeata* incorporation under flat planting increased the organic carbon content by 13.2% than under rice-wheat system. These findings are in agreement with the observations of Kharub *et al.* (2003), who reported that use of green-manuring over the years increased the organic C content. Nitrogen addition through green-manuring of *Sesbania aculeata* was almost double (92-99 kg/ha) than that through greengram (46-51 kg /ha) under flat-as well as bed planting system. This was mainly due to double production of dry biomass by *Sesbania aculeata,* because both the crops contain almost similar N content.

Cumulative infiltration rate was measured under chiselled and non-chiselled treatments. This was recorded for more than 8 hours. Initially chiselled as well as the non chiselled plots recorded similar infiltration rate, but after 3 hours the chiselled treatment recorded 17-23% higher cumulative infiltration rate than non-chiselled plots. This finding is in agreement with the observations of Sharma *et al.* (2003) and Sharma and Datta (1986), who also reported that breaking of hard pan improved the infiltration rate.

It may be concluded that green-manuring saved 25% N

Table 2. Rice-equivalent yield, land-use and production efficiencies of different treatments (mean basis)

Treatment	Rice-equivalent yield (t/ha)	Land-use efficiency (%)	Production efficiency (kg/ha/day)	Duration (days)	Cost of cultivation (x 10^3 Rs/ha)	Net returns (x 10^3 Rs/ha)	B : C ratio	Organic C (%) (0-15 cm depth)	pH
Chiselling									
With chiselling	15.21	72.05	57.83	263	57.13	28.73	1.505	0.409	7.58
Without chiselling	14.78	72.05	56.21	263	56.98	26.45	1.466	0.395	7.72
SEm±	0.07					0.44	0.011	0.011	0.08
CD (P=0.05)	NS					NS	NS	NS	NS
Crop sequences and planting methods									
Rice - wheat (bed)	14.65	72.05	53.70	263	53.78	28.94	1.538	0.362	7.82
Rice – wheat - greengram (bed)	14.95	87.39	46.86	319	59.13	25.25	1.427	0.429	7.80
Rice – wheat - *dhaincha* (bed)	14.65	87.39	45.91	319	57.88	24.78	1.428	0.363	7.54
Rice - wheat (flat)	15.03	72.05	57.13	263	54.03	30.76	1.569	0.397	7.37
Rice – wheat - greengram (flat)	15.30	87.39	47.96	319	59.38	26.96	1.454	0.424	7.69
Rice – wheat - *dhaincha* (flat)	15.41	87.39	48.30	319	58.13	28.83	1.496	0.438	7.66
SEm±	0.13					0.70	0.012	0.012	0.07
CD (P=0.05)	0.36					2.06	0.037	0.037	0.22

for rice crop and recorded higher rice-equivalent yield than rice-wheat system under flat planting. Planting wheat on bed recorded 6.5% lower grain yield than on flat. Taking green-manure crops increased the cost of cultivation (7.7%) and thereby decreased the net returns and benefit : cost ratio compared with conventional rice-wheat system. Inclusion of greengram either under flat or bed planting and *Sesbania aculeata* under flat planting increased the organic C content by 13.2% than rice-wheat system.

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