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Intensification is the Key for Sustainability of Rice-wheat System Productivity and Profitability in India

S.C. Tripathi[1], Subhash Chander[1] and Raj Pal Meena[1]*

Abstract: *Field experiment was conducted with inclusion of green gram and cowpea after wheat and vegetable pea in between rice and wheat under three different tillage (zero tillage, bed planting and conventional tillage) conditions. Tillage options were imposed for latter two crops only after Kharif season. All the intensification treatments recorded higher equivalent wheat yield as compared to rice-wheat system. Maximum equivalent wheat yield (152.13 q/ha), production efficiency (46.81 kg/ha/day), land use efficiency (89.04%), total return (Rs 1, 82,551/-ha), net return (Rs 49, 351/-ha) and B : C ratio (1.37) was recorded in rice-wheat -green gram cropping sequence under bed planting system. Approximately 81.66% higher net return was obtained with the adoption of green gram after wheat as compared to rice-wheat system alone. In contrast, these parameters were the lowest in rice-wheat system except production efficiency. This suggested that all the intensifications options are profitable as compared to rice-wheat system. Among the selection of three pulses, maximum profit was with green gram followed by cowpea and vegetable pea. Growing summer green gram could also avoid in pumping of water with additional benefits like increasing pulse production and saving of about 25% nitrogen requirement to succeeding rice crop.*

Keywords: *Cowpea, equivalent wheat yield, economics, green gram, land use efficiency, production efficiency, rice, vegetable pea, wheat.*

INTRODUCTION

Wheat and rice account for more than 50% of the world cereal production, and altogether these crops produce food grains for about 20% of the world population. In South Asia, rice-wheat crop sequence is the largest agriculture production system and occupies about 13.5 million hectares area including 10.3 million hectares in India, extending from Indo-Gangetic plains to Himalayan foothills.

In India, approximately 23 and 40% of total rice and wheat area, respectively, is represented by rice-wheat system alone (Timsina and Connor, 2001), which requires contrasting edaphic conditions. Rice is generally transplanted in puddled soil and is given continued submergence whereas wheat is grown in upland well-drained soils having good tilth. Rice-wheat system that yields 7 t/ha of rice and 4 t/ha of wheat takes up more than 300 kg nitrogen (N), 30 kg phosphorous (P) and 300 kg potassium (K) ha^{-1} from the soil. Continuous adoption of this system has been reported to decline soil and crop productivity (Nambiar and Abrol, 1989). Rice and wheat, both are high water requiring crops, having an evapo-transpiration requirement of more than 1000 mm. In the quest of high production, farmers have to irrigate these crops frequently, especially paddy, through surface water from canals and/or ground water pumped through shallow tube wells. This led to decline in water table, which is major cause of concerns in some parts of Indo Gangetic plain. Continuity of this trend will jeopardize the sustainability of rice-wheat system. Analysis of long-term experiments on rice-wheat (Dawe *et al*., 2000, Duxbury *et al*., 2000 and Yadav *et al*., 1998)

[1] Indian Institute of Wheat and Barley Research, Karnal -132 001, Haryana, India
* *Corresponding author. E-mail: subhtripathi@gmail.com*

showed rice yield decline @ 0.02 t ha^{-1} yr^{-1} or 0.5% yr^{-1}. On the other hand, in India, most of the oilseed and pulse crops are grown on flat bed by broadcasting with flood irrigation and/or under continental monsoonal type climate resulting in low productivity. Generally, these crops are susceptible to water stagnation, experienced during rainy season or flood irrigation. This prompted to investigate innovative planting techniques for these crops, which could enhance yield per se with lesser water use and also play a catalytic role in intensification of rice-wheat system.

The Resource Conservation Technologies (RCT's), which were evolved with the efforts of scientists, farmers, extension workers and private industry groups gained importance due to increased profit to farmers. The 'Bed Planting', an important input saving planting technique, especially water (20-30%), was introduced in India on the pattern of CIMMYT, Mexico. In this planting method, crop is grown on top of bed (40 cm) and irrigation is applied in furrows (30 cm). There are many additional benefits including lesser seed and nutrient requirement, opportunity for enhancing diversification and intercropping, moving towards conservation agriculture by using same beds for succeeding crops, reducing cost of cultivation, lesser lodging furrows providing efficient passage for irrigation as well as for drainage, increased surface area for capturing more rainfall, possibility of mechanized interculture operations as well as placement of fertilizer, manual and easy rouging, higher productivity of oilseed and pulses as compared to flat planting, additional window for maximizing yield with the help of interaction study of RCT's and wheat varieties.

Intensification of the rice-wheat system depends upon the duration of crops and availability of varieties, local demand, nutrient and water requirement and economics of system. The increases in rice yield were found to be greater on less fertile coarse-textured soils than on fertile medium and fine textured soils (Yadvinder Singh *et al.,* 1991). When there is yield benefit from green manure at low rates, it suggests that the only significant effect of the green manure is to increase N supply to the crop. When green manure has an effect on yield potential that no amount of fertilizer N can achieve, there is an indication that green manure provides benefits beyond N supply. Existence of this can be found in the work of Beri *et al.* (1989) and many others from Indo-Gangetic plain. Possible explanations for this response pattern may include more favourable physical, chemical, and biological conditions of the soil amended with green manure. Keeping the facts in view of enhancing pulse production, soil fertility, as well as sustainability, the present study was undertaken with the objective of enhancing productivity and profitability of the rice-wheat system.

MATERIALS AND METHODS

A field study was conducted for three consecutive years from 2007-08 to 2009-10 at Indian Institute of Wheat and Barley Research, Karnal (Latitude 29° 43′ N, longitude 76° 58′ E and altitude 245 m). The experimental soil was sandy clay loam in texture (15% clay), low in organic carbon (0.37%) and available N (145 kg/ha), medium in available P (17.2 kg/ha) and available K (155 kg/ha) content. The experiment was laid out in a randomized complete block design with three replications. The experimental treatments were rice-wheat green gram, rice-wheat-cowpea and rice-vegetable pea-wheat under zero tillage, bed planting and conventional tillage conditions and one rice wheat treatment as control. Rice crop was taken in puddled condition and thereafter treatments were imposed. Zero tillage, bed planting and conventional tillage options were imposed for wheat, green gram vegetable pea and cowpea crops. Rice (Gobind), green gram (SML 668), cowpea (Sukomal), vegetable pea (Arkel) and wheat (PBW 502 under timely sown and Raj 3765 under late sown after vegetable pea) crops were taken in system perspective. Timely sown wheat variety PBW 502 was sown after rice harvest in the 1st week of November month whereas late sown variety Raj 3765 was seeded after 2nd picking of vegetable pea in the 1st week of January month.

The rice and timely sown wheat crops were fertilized @ 150 kg N and 60 kg P_2O_5 and 40 kg K_2O/ha. Whereas late sown wheat crop was fertilized @ 120 kg N and 60 kg P_2O_5 and 40 kg K_2O/ha. No fertilizer was applied to green gram, cowpea and vegetable pea. This was done to utilize residual soil

Table 1
Yield of rice, wheat, greengram, vegetable pea and cowpea in different years and pooled

	Rice Yield (q/ha)				Wheat Yield (q/ha)				Green gram/Vegetable pea/cowpea yield (q/ha)			
Treatments	2007-08	2008-09	2009-10	Pooled	2007-08	2008-09	2009–10	Pooled	2007-08	2008-09	2009-10	Mean
Rice (TP)-Wheat (ZT)–green gram (ZT)	64.25	78.57	71.18	71.33	50.65	62.10	41.56	51.44	5.09	13.56	12.57	10.41
Rice (TP)-Vegetable pea (ZT)- Wheat (ZT)	64.74	81.07	64.24	70.02	17.66	28.69	26.92	24.42	33.62	69.44	45.17	49.41
Rice (TP)-Wheat (ZT)-Cowpea (ZT)	64.33	82.86	72.92	73.37	51.19	61.27	45.83	52.76	3.26	21.42	21.36	15.35
Rice (TP)-Wheat (bed)-green gram (bed)	65.81	82.50	69.44	72.58	56.35	54.44	48.92	53.24	5.03	15.19	13.94	11.39
Rice (TP)-Vegetable pea (bed)– Wheat (bed)	66.25	83.21	69.44	72.97	18.15	31.98	25.08	25.07	34.03	53.57	49.74	45.78
Rice (TP)-Wheat (bed)-cowpea (bed)	64.80	88.93	76.39	76.71	55.63	54.96	48.85	53.15	3.74	46.57	38.33	29.55
Rice (TP)-Wheat (CT)-green gram (CT)	65.60	78.57	67.71	70.63	50.67	61.39	42.16	51.41	4.94	13.94	11.58	10.15
Rice (TP)-Vegetable pea (CT)-Wheat (CT)	66.15	80.71	67.71	71.52	21.07	28.53	32.63	27.41	22.75	57.87	43.73	41.45
Rice (TP)-Wheat (CT)-Cowpea (CT)	65.08	81.07	67.71	71.29	49.07	60.60	43.38	51.02	2.97	23.41	22.17	16.18
Rice (TP)-Wheat (CT)	66.20	83.57	65.97	71.91	53.25	60.56	40.50	51.44	–	–	–	–
C D at 5%	NS	NS	6.59	5.63	5.38	4.22	8.66	3.79	–	–	–	–

fertility and reduce the cost of cultivation for intensification of rice-wheat system. Treatments consist of green gram and cowpea following rice received 25% less nitrogen in Kharif season. Full dose of phosphorous in the form of DAP and potash in the form of muriate of potash and one third dose of nitrogen in the form of urea was applied as basal i.e before sowing and remaining two third dose of nitrogen was top dressed in two equal splits in rice and wheat. Irrigation was applied as per need of the crop. Weeds in rice were controlled with the application of butachlor @ 1.0 kg/ha in 400 litre of water at 3-4 days after rice transplanting. Similarly weeds in wheat were controlled with the application of sulfosulfuron 25 g/ha in 400 liters of water at 30-35 days after sowing. All other recommended agronomic package of practices was adopted for green gram, cowpea and vegetable pea. Residues of these crops, after picking of pods, were incorporated into the soil as green manure. Equivalent wheat yield was calculated for each treatment by taking minimum support price of each crop in respective year. Cost of cultivation was calculated by taking into account the prevailing price of inputs like fertilizer, seed, herbicides, irrigations, tillage operations, transportation charges, management charges, rental value of land and depreciation cost of implements. Returns were calculated by taking minimum support price of rice, wheat and green gram and market price of cowpea and vegetable pea. Net returns were calculated by subtracting cost of cultivation from gross returns. Benefit:cost ratio was calculated by dividing gross returns with cost of cultivation.

The intensification in temporal dimension was measured in terms of land use efficiency, by taking total duration of crops in a crop sequence divided by 365 days. Production efficiency was calculated as equivalent wheat yield in a crop sequence divided by duration of sequence (Tomar and Tiwari, 1990). Rice and wheat yield and equivalent wheat yield were analyzed on yearly and combined over the year basis for comparison of treatments.

Table 2
Equivalent wheat yield and economics as affected by rice–wheat intensification options

	Equivalent wheat yield (q/ha)				Production Efficiency (kg/ha/day)	Land use Efficiency (%)	Economics (Rs/ha)			
Treatments	*2007-08*	*2008-09*	*2009-10*	*Pooled*			*Returns*	*Cost*	*Net return*	*B:C ratio*
Rice (TP)-Wheat (ZT)-green gram (ZT)	100.75	183.14	152.36	145.42	44.74	89.04	174498	127575	46923	1.37
Rice (TP)-Vegetable pea (ZT)-Wheat (ZT)	82.95	167.05	126.69	125.56	43.30	79.45	150675	128825	21850	1.17
Rice (TP)-Wheat (ZT)-Cowpea (ZT)	98.23	153.12	129.17	126.84	39.03	89.04	152206	128325	23881	1.19
Rice (TP)-Wheat (bed)-green gram (bed)	107.35	185.34	163.69	152.13	46.81	89.04	182551	133200	49351	1.37
Rice (TP)-Vegetable pea (bed)– Wheat (bed)	84.71	156.29	133.84	124.94	43.08	79.45	149934	134450	15484	1.12
Rice (TP)-Wheat (bed)-cowpea (bed) green gram (CT)	103.79	177.12	152.11	144.34	44.41	89.04	173206	133950	39256	1.29
Rice (TP)-Wheat (CT)-green gram (CT)	101.38	183.93	146.02	143.78	44.24	89.04	172533	133200	39333	1.30
Rice (TP)-Vegetable pea (CT)-Wheat (CT)	79.66	155.01	133.91	122.86	42.37	79.45	147433	134450	12983	1.10
Rice (TP)-Wheat (CT)-Cowpea (CT)	96.09	152.91	123.11	124.04	38.17	89.04	148847	133950	14897	1.11
Rice (TP)-Wheat (CT)	95.95	131.59	96.58	108.04	42.37	69.86	129648	120600	9048	1.08
C D at 5%	6.73	12.23	8.75	4.58						

TP = Transplanted, ZT = Zero tillage, CT = Conventional tillage, Bed = Bed planting

RESULTS AND DISCUSSION

Grain Yield and Equivalent Wheat Yield

Results presented in Table 1 revealed that rice yield was at par for first two years and in third year and in pooled analysis it was significant. Maximum rice yield (76.71 q/ha) was recorded in rice-wheat-cowpea treatment under bed planting followed by same treatment under zero tillage system. Effect of green manuring of green gram and cowpea just before rice transplanting was not visible on rice yield due to 25% lesser N application in these treatments. Lowest rice yield was recorded in rice-vegetable pea-wheat treatment. From pooled analysis of three years, wheat yield under different tillage conditions was at par when green gram or cowpea was taken. Maximum wheat yield (53.15 q/ha) was produced under bed planting system when green gram was taken after it. Wheat yield in different years was significant and the lowest yield was exhibited when wheat was sown after vegetable pea under very late sown condition. Among different years of study, the maximum wheat yield (62.10 q/ha) was recorded in zero tillage condition in 2008-09. Mean of three years showed that green gram, vegetable pea and cowpea yield ranged from 10.15 to 11.39 q/ha, 41.45 to 49.41 q/ha and 15.35 to 29.55 q/ha, respectively. Among tillage options, green gram and cowpea exhibited the maximum yield under bed planting whereas vegetable pea under zero tillage conditions. Though, there was variation in yield of pulses from one year to another.

Equivalent wheat yield was significantly higher in intensified cropping sequences in all the years under study and pooled basis (Table 2). From pooled basis, maximum and significantly higher equivalent wheat yield (152.13 q/ha) was obtained under rice-wheat-green gram crop sequence under bed planting than any other treatment followed by same treatment under zero tillage (145.42 q/ha). Rice-wheat-green gram crop sequence under bed planting gave the maximum equivalent wheat yield in all the three years under study. In contrast, rice-wheat crop sequence produced significantly lower equivalent wheat yield (108.04 q/ha) as compared to other crop sequences. Growing of vegetable in between rice and wheat produced significantly lower equivalent wheat yield than rice-wheat -green gram crop sequence irrespective of tillage options. Production efficiency was the maximum (46.81 kg/ha/day) in rice-wheat-green gram sequence under bed planting followed by same treatment under zero tillage (44.74 kg/ha/day) condition. However, the lowest production efficiency (38.17 kg/ha/day) was in rice-wheat-cowpea sequence under conventional tillage condition. Maximum (89.04%) land use efficiency was in rice-wheat-green gram/cowpea sequence and minimum (69.86%) in rice-wheat sequence. These observations were in agreement with findings of Chauhan *et al.* (2001).

In India, many farmers are taking summer rice by undermining the natural resources particularly water. Continuous adoption this practice is leading to depletion in ground water table and ultimately many farmers are forced to deepen their submersible tube well. The rate of fall in water table in Punjab per year was 18 cm during 1982-87; it increased to 42 cm during 1997-2002 (Hira *et al.*, 2004) and further to 75 cm during 2002-06 (Singh, 2006). To address this problem, it is duty of scientists to provide alternative solutions to this burning problem. To avoid summer/early rice cultivation, an effort was made to include pulse crops like green gram and cowpea in summer so that farmers can earn some money and their soil fertility could also be enhanced. There was not any increase in rice or wheat yield due to growing of these pulses. Probably this was due to 25% saving of nitrogen in rice crops where green gram or cowpea was incorporated. Beri *et al.* (1989) and Tripathi and Singh (2007) also suggested that green gram cultivation provides more benefits besides saving nitrogen in succeeding rice crop. Long term use of green gram or cowpea in rice-wheat system would certainly provide a sustainable rice-wheat system with improved soil physico-chemical properties. Higher net return in pulse intensification options was due to no fertiliser application in pulses, which further reduced the cost of cultivation.

Economics

Total return was the maximum (Rs 1,82,551/-ha) in rice-wheat-green gram under bed planting system followed by same treatment under zero tillage system (Rs 1,74,498/-ha). On the other hand, the lowest return was in rice-wheat system (Rs 1,29,648/-ha). Cost of cultivation was the maximum (Rs 1,34,450/-ha) in rice-vegetable pea-wheat sequence under bed planting and minimum (Rs 1,20,600/- ha) in rice-wheat sequence. Net return was maximum (Rs 49,351/-ha) in rice-wheat -green gram under bed planting system and minimum (Rs 9048/-ha) in rice-wheat system. Benefit : cost ratio was maximum (1.37) in rice-wheat -green gram either latter two crops grown under zero tillage or bed planting system and minimum (1.07) in rice-wheat system (Table 2). The lowest net return in rice-wheat system showed that farmers taking land on rent are least profitable. Higher profit with 300 cropping intensity was also reported by Chauhan *et al.* (2001). This suggests that there is need for intensification of rice-wheat system so that profit margin could be maximized to a great extent and at the same time cost of cultivation could also be minimized.

CONCLUSION

Three years study of intensification options reveals that growing pulses like green gram or cowpea after wheat or vegetable pea in between rice and wheat, across tillage practices, provided higher equivalent wheat yield, total return, net return and benefit cost ratio than rice-wheat system. This suggested that most favourable option for intensification of rice-wheat system is inclusion of green gram followed by cowpea and vegetable pea. Though, there was little increase in cost of cultivation by adopting intensification options but profit was much more than rice-wheat system. This will also provide employment to family labours of small and marginal farmers to a great extent besides saving of 25% nitrogen to rice crop.

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