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ROLE OF INTEGRATED NUTRIENT MANAGEMENT IN RESILIENCE PERFORMANCE OF RICE IN CENTRAL PUNJAB

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ABSTRACT

A long-term permanent plot experiment was conducted from 1983 to develop suitable integrated nutrient supply system for rice-wheat cropping system. The study was aimed to find out the effect of organic sources of nitrogen integrated with chemical sources on rice yield after 30 years of rice-wheat cropping system. Over the 30 years of study period, highest rice yield was obtained when 25% of nitrogen was supplied through green manuring (GM). When 25% N was supplied through farmyard manure (FYM), it produced rice yield at par with the treatment where, 100% NPK was applied through chemical fertilizers. Study showed that wherever, nitrogen was substituted through GM, FYM or wheat cut straw (WCS) in rice, grain yield was significantly higher as compared to the control. Corresponding increase in plant height favourably enhanced the LAI and it was found to be highest in the green-manured plots and lowest in control. Chlorophyll content index (CCI) was also found to be highest in T_{11}. As compared to 1983, the yield of rice increased in the plots fertilized with FYM, WCS and GM over the 30 years of research due to improvement in physical, chemical and biological properties of soil.

KEY WORDS
INM
NPK
LAI
CCI, productivity

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INTRODUCTION

Rice is the second most widely consumed cereal in the world next to wheat. It is the staple food for two third of the world's population. Over 2 billion people in Asia alone derive 80% of their energy needs from rice, which contains 80% carbohydrates, 7-8% protein, 3% fat and 3% fiber (Juliano, 1985). Rice (*Oryza sativa* L.) provides employment and livelihood security to 70 per cent of Indian population (Kulkarni *et al.,* 2015). In addition to being a staple food, rice is main constituent of life saving oral rehydration solution (ORS) (Ahuja *et al.,* 2008). Inspite of huge increase in productivity of this crop, India is the largest consumer of rice also because it is heavily consumed by more than half of the country's population. Considering these facts in mind it is very important to plan the strategies to increase the yield and maintain its productivity over the years as rice is exhaustive nutrient feeder. To meet nutrient needs of this crop, fertilizers are added but their prolonged use affect the sustainability of crop production and soil fertility. The use of chemical fertilizers not only improves crop yield, but their application directly or indirectly causes series of changes in physical, chemical and biological properties of soil. These changes in long term have significant influence on the quality and productive capacity of the soil (Divya *et al.,* 2012). Maintaining and improving soil fertility for sustainable agriculture is becoming more crucial due to increasing complexity of the nutritional problems. The integrated nutrient management system will have a strong impact on soil fertility and may need to be taken into consideration in the development of fertilizer recommendations. Conjoint use of fertilizers and manures would not only impart sustenance to the production and improve soil health, but also enhance the efficient use of applied nutrients. The integrated plant nutrient supply (IPNS) system appears to be most potential and promising strategy for restoration and sustaining soil health and productivity (Singh *et al.*, 1998). Therefore, in order to assess its effect on soil environment, the present study has been undertaken with an objective to study the effect of organic and inorganic fertilization on productivity of rice on long term basis.

MATERIALS AND METHODS

A long-term field experiment on integrated nutrient management in rice-wheat system was initiated in 1983 on permanent plots at Agronomy farm of Punjab Agricultural University, Ludhiana representing the Indo-Gangetic alluvial plains and situated at 30º56' N latitude and 75º52' E longitudes with an altitude of 247 meter above the mean sea level. The climate of the experimental site is sub-tropical and semi-arid type with hot and dry summer from April to June followed by hot and humid period during July to September, cold winters during November to January and mild climate from February to March. The mean annual rainfall over the area is 730 mm. The soil of experimental site is sandy loam and the soil contained 171 kg ha^{-1} of $KMn0_4$ extractable nitrogen, 21.4 kg ha^{-1} 0.5 *M* sodium bicarbonate $NaHC0_3$) extractable phosphorus, 104 kg ha^{-1} 1 M ammonium acetate

extractable potassium and 0.37% organic carbon. The 14 treatments consisting of combinations of chemical fertilizers and organic sources of nutrients in rice and only chemical fertilizers at different levels in wheat were tested in randomized block design with three replications (Table 1). From the start of the experiment till 1992, treatment T_{12} was being taken as control but after the year 1992, treatment T_{12} was added to the experiment. The recommended doses of fertilizers were 120:30:30 and 120:60:30 (N: P_2O_5: K_2O kg ha^{-1}) for rice and wheat, respectively. The N, P and K were supplied through urea, single super phosphate and murate of potash, respectively. Nitrogen was supplemented in the respective treatments either through green manure *in situ* (GM), farmyard manure (FYM) or wheat straw (WCS), so that 100% recommended N dose could available to the rice crop. *Sesbania* (45-days-old) was incorporated 1 to 2 days before transplanting of rice. Green manure (GM) was grown according to recommended seed rate well before rice transplanting. The content of nitrogen in GM crop was determined by taking random sample of dry weight collected from one square metre area at 45 days after sowing. On the basis of nitrogen content in one square metre area, the remaining part of N-requirement of a particular treatment was estimated. FYM and WCS were incorporated into the soil 10 to 15 days before transplanting as per the treatments. Periodic plant height was recorded at 30, 60 and 120 DAT and at harvest of rice. The periodic leaf area index (LAI) at 30, 60, and 120 DAT of rice was recorded by using the Sun Scan Canopy Analyzer, Model: Sun Scan type SS1, Manufactured by Delta-T Devices, Cambridge-England. Chlorophyll content index (CCI) was recorded periodically at 30, 60 DAT and at harvest stage of crop by SPAD meter.

RESULTS AND DISCUSSION

Plant height

Data pertaining to plant height was influenced significantly by sustainable intensification practices at all the growth stages of rice during both the years of study (Table 2). At 30 and 60 DAT the highest plant height was obtained in treatment T_{11} (67.91 cm in 2013 and 64.70 cm in 2014) when 25 per cent N was substituted by GM along with 75 per cent of recommended NPK dose through chemical fertilizers in *kharif* season followed by 75 per cent of recommended NPK dose through chemical fertilizers in *rabi* season. Treatment T_{11} was found significantly higher than T_1 (control) and was statistically at par with T_5 (100 per cent of recommended NPK dose through chemical fertilizers in rice and wheat crop) and T_6 when 50 per cent N was substituted by FYM in *kharif* season while 100 per cent of recommended NPK was applied through chemical

Table 1: Treatments of the experiment

Treatment	*Kharif* (Rice-*var PR 118*)	*Rabi* (Wheat-*var HD 2967*)
T_1	No fertilizer, no organic manure (control)	No fertilizer, no organic manure (control)
T_2	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers
T_3	50% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_4	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers
T_5	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_6	50% recommended NPK dose through fertilizers + 50% N through FYM	100% recommended NPK dose through fertilizers
T_7	75% recommended NPK dose through fertilizers + 25% N through FYM	75% recommended NPK dose through fertilizers
T_8	50% recommended NPK dose through fertilizers + 50% N through wheat cut straw (WCS)	100% recommended NPK dose through fertilizers
T_9	75% recommended NPK dose through fertilizers + 25% N through wheat cut straw (WCS)	75% recommended NPK dose through fertilizers
T_{10}	50% recommended NPK dose through fertilizers + 50% N through green manuring (*sesbania*)	100% recommended NPK dose through fertilizers
T_{11}	75% recommended NPK dose through fertilizers + 25% N through green manuring (*sesbania*)	75% recommended NPK dose through fertilizers
T_{12}	100% recommended NPK dose through fertilizers + 50% N through FYM	100% recommended NPK dose through fertilizers
T_{13}	$N_{180}P_{30}K_{30}$	$N_{150}P_{60}K_{30}$
T_{14}	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers + cowpea in summer with recommended N

Table 2: Effect of chemical fertilizer and organic manures on periodic plant height of rice

Treatments	30 DAS		60 DAS		120 DAS		At Harvest	
	2013	2014	2013	2014	2013	2014	2013	2014
T_1	43.25	41.10	57.29	56.46	68.22	67.50	69.33	68.67
T_2	46.82	45.20	68.87	65.00	81.78	80.30	82.55	81.60
T_3	47.51	46.70	71.49	68.39	83.93	82.70	85.71	83.53
T_4	51.98	49.53	74.23	70.89	86.60	84.50	88.90	84.87
T_5	60.27	57.38	81.58	76.99	96.22	91.37	98.41	94.83
T_6	65.87	61.40	83.65	80.87	100.18	99.50	101.21	100.23
T_7	66.08	60.06	85.38	82.74	100.56	99.90	101.48	101.07
T_8	57.89	56.46	76.40	74.05	91.83	91.30	94.26	92.40
T_9	58.74	52.83	77.87	71.82	93.44	88.60	96.50	90.33
T_{10}	66.58	61.50	85.94	83.79	100.93	100.30	101.58	101.83
T_{11}	67.91	64.70	88.62	85.77	105.61	103.70	106.85	104.53
T_{12}	67.22	62.90	87.46	84.03	102.77	100.30	103.80	101.80
T_{13}	66.93	61.20	86.51	83.00	101.26	99.19	101.96	100.13
T_{14}	62.46	58.63	81.55	77.95	98.64	95.60	100.76	97.77
CD (p=0.05)	9.94	7.35	8.22	9.16	8.63	11.28	7.72	9.65

Table 3: Effect of chemical fertilizer and organic manures on periodic LAI of rice

Treatment	30 DAS		60 DAS		120 DAS	
	2013	2014	2013	2014	2013	2014
T_1	0.86	0.74	0.98	0.80	1.03	0.94
T_2	1.33	1.25	1.50	1.40	2.11	1.97
T_3	1.36	1.31	1.96	1.80	2.56	2.64
T_4	1.39	1.33	2.26	2.10	2.63	2.55
T_5	1.62	1.38	2.51	2.40	3.19	2.93
T_6	1.70	1.47	2.63	2.60	3.60	3.56
T_7	1.71	1.49	2.81	2.50	3.77	3.49
T_8	1.42	1.36	2.31	2.26	2.81	2.97
T_9	1.41	1.35	2.47	2.38	3.11	2.89
T_{10}	1.76	1.50	3.11	2.90	3.91	3.88
T_{11}	1.79	1.51	3.42	3.10	4.22	3.91
T_{12}	1.78	1.58	3.38	3.30	4.17	3.11
T_{13}	1.81	1.52	3.23	3.20	4.03	3.08
T_{14}	1.64	1.40	2.54	2.42	3.49	3.22
CD (p=0.05)	0.19	0.12	0.33	0.74	0.99	0.93

Table 4: Chlorophyll Content Index (CCI) of rice as influenced by chemical fertilizers and organic manures

Treatment	30 DAS		60 DAS		At harvest	
	2013	2014	2013	2014	2013	2014
T_1	6.57	5.19	20.55	19.87	32.58	29.63
T_2	9.34	7.73	25.61	23.10	38.46	35.50
T_3	10.88	8.25	28.77	27.43	41.59	39.80
T_4	11.27	9.09	29.58	28.20	42.35	41.23
T_5	13.33	10.85	31.23	29.56	44.52	42.90
T_6	14.22	12.08	35.71	31.73	45.28	43.70
T_7	14.58	12.44	36.44	32.77	45.90	44.53
T_8	12.15	9.85	30.26	28.63	43.21	41.17
T_9	12.34	10.13	30.83	29.57	43.75	41.57
T_{10}	15.36	13.88	37.48	33.50	46.38	44.73
T_{11}	17.63	16.58	39.43	38.13	48.66	46.43
T_{12}	16.33	17.53	39.12	37.66	48.20	45.77
T_{13}	16.08	15.64	38.54	36.65	47.25	46.13
T_{14}	13.49	11.87	33.68	32.07	44.93	42.73
CD (p=0.05)	5.63	4.30	4.10	4.21	3.56	4.01

fertilizers. At 120 DAT significantly lower plant height was found in treatment T_8 (when 50 per cent N was being substituted by WCS in *kharif* season followed by 100 per cent NPK dose through chemical fertilizers in *rabi* season) and treatment T_9 (25 per cent N was applied through WCS in addition to 75 per cent NPK through chemical fertilizers in rice crop followed by 75 per cent of recommended NPK dose through chemical fertilizer) as compared to treatment T_{11} during 2013 and 2014. Similarly, at 120 DAT, at harvest tallest plants (106.85 cm and 104.53 cm during 2013 and 2014 respectively) were recorded in treatment T_{11} when 25 per cent N is substituted by GM along with 75 per cent of recommended NPK dose through chemical fertilizers in *kharif* season followed by 75 per cent of recommended NPK dose through chemical fertilizers in *rabi* season. Similar results were obtained by Singh *et al.,* 2013 and they reported that integrated nutrient management (INM) resulted in higher plant height with longer leaves than chemical fertilizer alone in both the rice varieties (Pusa Basmati 1 and Pusa 44).

Leaf Area Index (LAI)

At 30 DAT, LAI was found to significantly lower in control (T_1) as compared to 100 per cent recommended chemical fertilizers in *kharif* and *rabi* i.e. T_5 (Table 3). Treatment T_5 was statistically at par with the highest value of LAI in 2013 i.e. 1.81 (T_{13}, when 180 kg N, 30 kg, P_2O_5 and 30 kg K_2O was applied in rice crop followed by 150 kg N, 60 kg P_2O_5 and 30 kg K_2O in wheat crop) but in 2014 treatment T_{12} (50 per cent N was added through FYM with 100 per cent recommended NPK through chemical fertilizers in *kharif* followed by 100 per cent recommended NPK added through chemical fertilizers) was highest in LAI (1.58) and was statistically at par with treatments in which N was substituted by 25 per cent and 50 per cent through FYM and GM while the treatments in which the N was being substituted 25 per cent and 50 per cent through WCS were significantly lower in LAI as compared to treatment T_{12}. At 60 DAT the LAI was found to be significantly lower in T_5 (100 per cent of recommended NPK through chemical fertilizers in *kharif* followed by 100 per cent recommended NPK through chemical fertilizers in *rabi*) as compared to T_{12} during 2013 and T_{11} during 2014. While addition of NPK only through chemical fertilizers was found to be significantly higher as compared to control (T_1). At 120 DAT, during both the years the LAI was found to be highest in T_{11} (25 per cent N

Table 5: Effect of chemical fertilizer and organic manures on grain yield of rice after 30 years

Treatment	Grain yield (q ha^{-1})	
	1983	2013
T_1	21.4	15.25
T_2	40.0	35.85
T_3	35.7	37.88
T_4	41.6	45.60
T_5	45.7	66.45
T_6	41.0	68.25
T_7	41.9	69.90
T_8	39.6	57.45
T_9	42.9	58.78
T_{10}	45.9	71.31
T_{11}	43.4	72.80
T_{12}	27.2	72.25
T_{13}	43.1	71.52
T_{14}	45.8	66.75
CD (p = 0.05)	-	3.82

was applied through GM in addition to 75 per cent NPK through chemical fertilizers in rice crop followed by 75 per cent of recommended NPK dose through chemical fertilizer to wheat crop) and was statistically at par with treatments when N was substituted 25 per cent and 50 per cent through FYM and GM but was significantly higher than treatments in which 25 per cent and 50 per cent N was substituted through WCS. Similar results were also obtained by Dalai, 1999.

Chlorophyll content index (CCI)

Chlorophyll content index was recorded periodically at 30, 60 and at harvest stage of rice with the help of SPAD and it was found that there was consistent increase in the value of CCI with the advancement age of the crop (Table 4). CCI is the relative greenness of the crop and it is directly responsible for photosynthesis of the crop. During the study, it was found that significant differences were found among the different treatments comprising of organic and inorganic sources of nutrition. At 30 DAT the control (T_1) was significantly lower in CCI (6.57) as compared to treatment T_5 (13.33). However, T_5 was statistically at par with T_{11} during 2013 but in 2014 it was observed that when 50 per cent N was added through FYM along with 100 per cent recommended NPK dose through chemical fertilizers in *kharif* followed by 100 per cent recommended NPK through chemical fertilizers produced in *rabi* produced significantly higher CCI (17.53) as compared to T_5 (10.85) treatment. At 60 DAT of rice it was found that when 25 per cent N was substituted by GM (T_{11}) the CCI was significantly higher (39.43 in 2013 and 38.13 during 2014) as compared to treatment T_5 and control (T_1). Similarly, at harvest it was observed that when N was substituted 25 per cent and 50 per cent by FYM and GM and CCI was significantly higher as compared to control (T_1) and were statistically at par with each other. However, WCS treated plots were found to be statistically at par with 100 per cent recommended NPK dose through chemical fertilizers.

Grain yield

Grain yield is the main criterion for judging the comparative efficacy of different treatments. The data in Table 5 showed that the grain yield of rice increased appreciably with the application of inorganic and organic manures as compared to control where no fertilizer or manures were added. Increased grain yield with increased levels of NPK may be due to the fact that these nutrients are directly involved in the growth, development and ultimately the yield of crop. On long term basis it was observed that the grain yield increases in the treatments where FYM and GM (*Sesbania*) were incorporated into the soil along with chemical fertilizers. When 25% of N was substituted through FYM and GM (*Sesbania*), the grain yield was found significantly higher than control (T_1). Treatment T_{11} produced significantly higher grain yield (72.80 q ha^{-1} during 2013) as compared to treatment T_5. Singh and Verma (1999) and Bhandari *et al.* (1992) also found that the combined use of organic and inorganic sources of nutrients significantly affects the grain yield of rice. When the N was substituted about 25 per cent and 50 per cent by WCS, the grain yield was found to be significantly low as comparison to treatments in which 25 per cent and 50 per cent N was substituted through FYM and GM (*Sesbania*) but was significantly higher than control (T_1). Application of 100 per cent of recommended NPK through chemical fertilizer was found to improve the yield by 335.7% (2013) over control (T_1) of rice on the term basis.

During 1983, the highest grain yield was observed in T_5 (45.7 q ha^{-1}), T_{10} (45.9 q ha^{-1}) and T_{14} (45.8 q ha^{-1}) treatments. While lowest grain yield was found in control (21.4 q ha^{-1}) plots. It was observed over the 30 years of research that with the addition of FYM, WCS and GM there was significant increase in the grain yield of rice in the rice-wheat system although both the crops are highly nutrient exhausted crops. So, it can be concluded that the FYM, GM and WCS added nutrients to the soil and improve the physical, chemical and biological properties of soil and ultimately enhance the productivity of rice on long term basis. The synergistic effect of FYM has also been accrued but its magnitude was slightly lower than the green manure. Yield increase in these treatments was due to positive influence of balanced source-sink relationship. Moreover, with the combined use of different organic and inorganic sources of nutrients there was less load of chemicals over the soil as about 50 per cent chemical fertilizers were saved during the rice-wheat system as about 25 per cent of chemical fertilizers were saved during *kharif* and 25 per cent during *rabi*, but the productivity of rice increases on the long term basis.

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