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Research Paper

Productivity and quality of basmati rice (*Oryza sativa*) in relation to nitrogen management

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ABSTRACT

A field experiment was conducted at the Punjab Agricultural University, Ludhiana during 2010 and 2011 to study the effect of different sources of nitrogen on productivity and quality of basmati rice (*Oryza sativa* L.). The experiment was conducted in randomized block design with 9 treatment combinations of chemical fertilizer, green manuring with sunnhemp (*Crotalaria juncea* L.) and farmyard manure (FYM) with 4 replications. Incorporation of green manure 50 days after its sowing resulted in statistically same grain yield (3.05 t/ha) as that with recommended nitrogenous fertilizer (3.06 t/ha) and different combinations of organic manures with nitrogenous fertilizer. There was no significant effect of additional application of chemical fertilizer or FYM to green manuring on the grain yield. Green manure, having supplied 77.2 kg N/ha, alone was sufficient to meet the recommended nitrogen requirement (40 kg/ha) of basmati crop. Application of FYM (19.8 t/ha) to supply 40 kg N/ha alone resulted in significantly lower grain yield (2.65 t/ha) than all the other combinations of nutritional sources. The quality parameters (brown and milled rice recovery, minimum cooking time, water absorption ratio, elongation ratio and cooking coefficient) were statistically at par among all the nitrogen sources except brown and milled rice recoveries which were significantly lower with FYM alone. Head-rice recovery and protein content of grains with different nitrogen sources were comparable to that produced with chemical fertilizer except green manure supplemented with FYM or FYM supplemented with 50% of recommended nitrogen which had significantly higher values of these two parameters than the chemical fertilizer. Improvement in soil organic carbon and available N, P, K was observed with green manuring and FYM as compared to chemical fertilizer alone. The benefit: cost ratio was the highest with chemical fertilizer alone due to its lowest cost.

***Key words* :** *Basmati* rice, FYM, Green manure, Grain yield, Nitrogen, Quality

Rice is a major crop of Indo-Gangetic plains being mainly grown in rice–wheat cropping system on an area of about 12 million ha (Bhatt *et al*., 2016). Its intensive cultivation has caused considerable damage to the environment and natural resources due to excessive use of agrochemicals and production of methane under puddled conditions (Dhaliwal *et al*., 2014). Thus, more and more emphasis is being laid on developing good agricultural practices (GAPs) to raise this crop. Productivity and quality of basmati rice depends on the environmental conditions and the agronomic management practices (Singh *et al*., 2006). The nitrogen requirement of basmati rice varies from 20-40 kg/ha, depending on the variety (PAU, 2016). The low nitrogen requirement of *basmati* rice and coincidence of its growing season with the rains are good for the conservation of natural resources and environmental health.

Nitrogen management in *basmati* rice is a very critical issue in its production. Its higher dose than recommended results in increased incidence of insect-pests, diseases and crop lodging thus affecting its grain quality (Chau and Heong, 2005). Moreover, in summer-grown flooded rice, significant nitrogen losses occur via nitrate leaching and denitrification (Aulakh *et al*., 2001) leading to nitrate contamination of groundwater (Aulakh *et al*., 2009) and emission of N_2O (Aulakh and Adhya, 2005). Integrated approach of nutrient management is a significant component of GAPs. Organic manures are a vital component of integrated nutrient management and in addition to supplying nutrients to crop, also improve physical and biological conditions of soil (Kumari *et al*., 2010). They provide regulated supply of nitrogen by its slow release resulting

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in increased yields of rice and higher nutrient-use efficiency (Sharma, 2002). Venkatakrishnan and Ravichandran (2012) reported higher available N, P and K content of soil with application of organic manures alone or as a component of integrated nutrient management as compared to recommended chemical fertilizers.

The important green manure crops in north-western India include sunnhemp (*Crotalaria juncea* L.), sesbania (*Sesbania aculeata* L.), clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] and cowpea [*Vigna unguiculata* (L.) Walp.]. Green manuring results in the same rice yields as with 120 kg N/ha through urea and green manuring done prior to rainy (*kharif*) season crop also contribute towards nutrition of wheat in winter season (*rabi*) under Punjab conditions (Aulakh *et al*., 2000). The higher nitrogen uptake rates by rice with green manure than from urea indicate a better synchrony between green manure nitrogen availability and nitrogen uptake by rice. The available Fe status of soil increases with the incorporation of *sesbania* green manure prior to transplanting rice in the coarse-textured soils of Punjab (Nayyar and Chhibba, 2000). Farmyard manure (FYM) occupies an important place amongst bulky organic manures because of its availability at household level, though in limited quantity. The physical, chemical and biological properties of soil improve with application of farmyard manure (FYM), thereby improving the nutrient availability in soils (Gill and Walia, 2014). Nitrogen-use efficiency increases with application of urea in combination with farmyard manure (FYM). The combined application of green manure, crop residues and composts along with liquid manures mainly *beejamrut*, *jeevamrit*, *panchagavya*, *sasyamrut* and vermiwash etc. can release the nutrients as per the needs of crop to sustain higher productivity (Kanwar *et al.*, 2006).

Less nitrogen requirement of basmati rice can easily be met through organic sources, viz. green manure, farmyard manure, and thus even the crop can be successfully grown under organic farming situations. The studies were initiated during the *kharif* 2010 with the objectives to explore the possibility of growing basmati rice with organic manures and investigate the effect of organic sources of nutrition on its grain quality. The objective of skipping chemical fertilizer was to see the potential of organic manure in raising organic basmati crop, as it has great demand in organic food market and is well fitted in organic basmati rice–wheat–summer mungbean cropping system. Integration of different doses of urea as source of nitrogen was aimed at to see if the conventional crop needs additional nitrogen to the green-manured or farmyard-manured crop.

MATERIALS AND METHODS

A field experiment was conducted during the rainy season (*kharif*) of 2010 and 2011 on semi-arid, irrigated, Tolewal loamy sand (Typic Ustochrept) soil at the Punjab Agricultural University, Ludhiana (30°56' N and 75°52' E, with a mean height of 247 m above the mean sea-level), Punjab. The experiment soil was loamy sand in nature with pH 7.3, organic carbon 4.5 g/kg, available nitrogen 162.6 kg/ha, available phosphorus 17.1 kg/ha and potassium 185.7 kg/ha. The groundwater table was below 8 m. The experiment was conducted in a randomized block design with 9 treatment combinations of chemical fertilizer (urea), green manuring (GM) with sunnhemp and farmyard manure (FYM) with 4 replications. The treatments included recommended nitrogen (RN) 40 kg N/ha, green manure (GM), GM + 25% RN, GM + 50% RN, farmyard manure to supply 40 kg N/ha (FYM), FYM + 25% RN, FYM + 50%RN, FYM+GM and unfertilized control.

Sunnhemp as green-manure crop was sown after wheat harvesting in the last week of May by broadcasting 50 kg seed/ha on a well-prepared seedbed. The green-manure crop produced above-ground dry biomass to the tune of 3.2 and 3.8 t/ha during 2010 and 2011 respectively which was incorporated directly in the soil with a disc plough at 50 days after sowing as per the treatments. The green manure biomass of 3.2 and 3.8 t/ha contributed 70.7 and 83.6 kg N/ha to the soil during 2010 and 2011, respectively. A well-rotten farmyard manure having 1.1% N, 0.2% P and 0.5% K was evenly spread and incorporated into the soil to supply 40 kg N/ha according to the requirement of treatments.

Basmati rice variety ‘Punjab Basmati 2’ was sown in a nursery on 17 June 2010 and 29 June 2011 with a seed rate of 20 kg/ha and was transplanted at a spacing of 20 cm × 15 cm (33 hill/m^2) on 15 July 2010 and 28 July 2011, respectively. Nitrogen @ 40 kg/ha as per the recommendation (PAU, 2016) was applied as urea in two equal splits at 3 and 6 weeks after transplanting the crop as per the treatments. Phosphorus was not applied to basmati rice as recommended phosphorus had been applied to preceding wheat crop (PAU, 2016). The crop field was kept ponded with water during the first fortnight after transplanting and thereafter intermittent irrigations were given after 2 days of disappearance of irrigation water as per the recommendations of the PAU, Ludhiana. The source of irrigation water was tubewell. Grain yield was recorded by harvesting an area of 21 m^2 from a plot size of 36 m^2. Grain and straw yields were expressed on 14% moisture and dry-weight basis, respectively. Concentration of nitrogen in grains was determined by the micro-Kjeldahl method. The methods for calculating rice recoveries, water-absorption ratio and cooking coefficient were as under:

$$\text{Brown rice recovery (\%)} = \frac{\text{Brown rice obtained (g)}}{\text{Total paddy taken (g)}} \times 100$$

$$\text{Milled rice recovery (\%)} = \frac{\text{Milled rice obtained (g)}}{\text{Total paddy taken (g)}} \times 100$$

$$\text{Head rice recovery (\%)} = \frac{\text{Head rice obtained (g)}}{\text{Total paddy taken (g)}} \times 100$$

$$\text{Water absorption ratio} = \frac{\text{Weight of cooked grains (g)}}{\text{Weight of raw grains (g)}} \times 100$$

$$\text{Cooking coefficient} = \frac{Lc - Lr}{Bc - Br}$$

where, Lc, Length of cooked grain (mm); Lr, length of raw grain (mm); Bc, breadth of cooked grain (mm); Br, breadth of raw grain (mm)

$$\text{Elongation ratio} = \frac{Lc}{Lr}$$

where, Lc, Length of cooked grain (mm); and Lr, length of raw grain (mm)

The benefit: cost ratio was calculated by using cost of cultivation and net returns data. The two-year data were pooled and statistically analyzed by using statistical methods described by Gomez and Gomez (1984) and the software used was CPCS1 developed by the Department of Statistics, Punjab Agricultural University, Ludhiana.

RESULTS AND DISCUSSION

Plant height

The plant height with green manuring (T_2), combinations of green manuring and chemical fertilizer (T_3 and T_4), FYM (T_5) and combination of FYM with chemical fertilizer (T_6 and T_7) did not differ significantly from the recommended nitrogen application (T_1) except GM + 50%RN (T_4) where plant height was significantly higher than the recommended nitrogen (Table 1). The higher plant height with GM + 50%RN (T_4) might be due to excess supply of nitrogen owing to tendency of basmati rice to attain more height with excessive nitrogen. High doses of nitrogen cause excessive vegetative growth and plant height (PAU, 2016). Mannan *et al*. (2010) also reported increased plant growth with higher level of N leading to lodging of crop which increased spikelet sterility and lowered the grains/panicle.

Yield attributes

Green manuring alone (T_2), and different combinations of green manuring, FYM and chemical fertilizer (T_3,T_4,T_6,T_7 and T_8) had statistically similar yield attributes (effective tillers/m^2, 1,000-grain weight, panicle length, filled grains/panicle) as that with recommended nitrogen (T_1) (Table 1). However, FYM alone (T_5) recorded significantly lower yield attributes than the recommended nitrogen (T_1) and it might be due to less supply of nitrogen to the crop from FYM as whole nitrogen present in FYM is not mineralized and becomes available to the first crop. Solunke *et al*. (2006) and Pandey *et al.* (2007) also reported more number of filled grains/panicle with the combined use of FYM and reduced dose of fertilizers than FYM alone.

Grain and straw yields

Green manuring alone (T_2) and different combinations of green manuring, FYM and chemical fertilizer (T_3,T_4,T_6,T_7 and T_8) resulted in statistically similar grain yields as that with the recommended chemical fertilizer (T_1) (Table 1). However, FYM alone (T_5) resulted significantly less grain yield than the recommended nitrogen (T_1). The application of FYM when supplemented with 25% recommended nitrogen (T_6) showed significantly less grain yield than that when FYM was supplemented with 50% fertilizer nitrogen (T_7) or green manuring was supplemented with FYM (T_8).

The statistically same grain yield with green manuring and with different combinations of green manuring, FYM and chemical fertilizer to that of recommended nitrogen might be due to continuous supply of nutrients with these sources throughout the crop growth period as in case of split application of chemical fertilizer (Table 1). Balasubramaniyan (2004) reported the highest grain yield (3.9 t/ha) of rice with the combination of green manure and nitrogen fertilizer as compared to application of green manure alone (3.0 t/ha). The green manuring alone was sufficient to meet nitrogen requirement of basmati rice as that supplied with chemical fertilizer and thus, additional application of chemical fertilizer to green manuring did not increase the grain yield. This might be due to sufficient supply (70.7–83.6 kg N/ha) of nitrogen by green manuring only. Similar results with green manuring have also been reported in coarse rice where green manuring resulted same yields as that with 120 kg N/ha through chemical fertilizer (Aulakh *et al.*, 2000). Aulakh *et al*. (2001) also reported higher mineral N levels for a longer period with green manuring as compared to chemical-N alone. The lower grain yields with FYM alone (T_5) than recommended nitrogen (T_1) might be due to slow non-synchronized release of nitrogen from FYM. Moreover, the whole nitrogen present in the FYM does not become available to the first crop of its application. The significantly lowest grain yield of 2.38 t/ha in unfertilized control plot indicated the inherent potential of soil to produce the yields.

Thus, green manure alone is sufficient to raise a successful crop of basmati rice but FYM needs integration with chemical nitrogenous fertilizer at 25–50% of recommended nitrogen to act as booster for release of nitrogen and maintaining optimum C: N ratio in the soil. The integration of FYM and chemical fertilizer might have synergistic effect on growth and yield. The consistent N supply owing to slow release from the application of FYM along with chemical fertilizer matched with the absorption pattern of rice resulting in improved crop yield (Yadav and Yadav, 2015).

The straw yields with green manuring (T_2), FYM (T_5) and their different combinations (T_3,T_4,T_6,T_7, T_8) were statistically similar to that with recommended nitrogen (T_1) indicating that FYM when applied alone contributed to the plant height and foliage but was unable to contribute towards grain yield. The FYM when integrated with 50% RN resulted in significantly higher straw yield than FYM alone but its integration with 25% RN was statistically at par with FYM alone.

Grain quality

Green manuring alone (T_2) and different combinations of green manuring, FYM and chemical fertilizer (T_3,T_4,T_6,T_7 and T_8) had statistically similar brown and milled-rice recoveries as that with recommended nitrogen (T_1) (Table 2). Application of FYM alone (T_5) recorded significantly lower brown and milled rice recoveries than

Table 1. Effect of nitrogen treatments on growth, yield attributes and grain yield of basmati rice (mean over 2 years)

Treatment	Plant height (cm)	Effective tillers/m^2	Panicle length (cm)	Filled grains/ panicle	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1 (RN)	108.0	221.0	27.9	93.4	23.5	3.06	6.07
T_2 (GM)	106.0	219.0	27.8	93.6	23.4	3.05	6.11
T_3 (GM + 25% RN)	111.1	226.5	28.3	89.2	23.3	3.03	6.18
T_4 (GM + 50% RN)	114.3	228.0	28.6	88.6	23.4	3.11	6.20
T_5 (FYM)	104.8	196.5	26.8	84.8	22.5	2.65	5.64
T_6 (FYM + 25% RN)	107.9	224.0	27.7	91.0	23.2	2.92	5.94
T_7 (FYM + 50% RN)	108.8	233.5	28.5	98.4	23.8	3.16	6.29
T_8 (FYM + GM)	109.8	228.5	28.2	98.3	23.6	3.16	6.38
T_9 (Control)	91.9	175.5	25.3	76.0	21.1	2.38	5.27
SEm±	1.17	4.30	0.33	2.47	0.27	0.07	0.17
CD (P=0.05)	3.5	12.9	1.0	7.4	0.8	0.21	0.52

T_1, (RN), Recommended nitrogen 40 kg N/ha; T_2, (GM), green manure; T_3, GM + 25% RN; T_4, GM + 50% RN; T_5, (FYM) farmyard manure to supply 40 kg N/ha; T_6, FYM + 25% RN; T_7, FYM + 50% RN; T_8, FYM + GM; T_9, unfertilized control

Table 2. Effect of nitrogen treatments on grain and cooking quality of basmati rice (mean over 2 years)

Treatment	Rice recovery (%)			Minimum cooking time (min)	Water absorption ratio	Elongation ratio	Cooking coefficient	Protein content (%)
	Brown	Milled	Head					
T_1 (RN)	77.7	68.4	54.4	16.44	3.27	1.61	5.45	7.37
T_2 (GM)	77.6	68.9	55.5	16.46	3.22	1.62	5.71	7.36
T_3 (GM + 25% RN)	76.7	68.1	52.9	16.45	3.15	1.60	5.45	7.40
T_4 (GM + 50% RN)	76.2	67.2	52.4	16.35	3.16	1.56	5.68	7.48
T_5 (FYM)	74.8	65.9	51.1	16.30	3.13	1.58	5.48	7.18
T_6 (FYM + 25% RN)	77.3	69.6	54.2	16.42	3.21	1.57	5.56	7.18
T_7 (FYM + 50% RN)	78.7	70.3	57.3	16.48	3.26	1.63	5.58	7.66
T_8 (FYM + GM)	78.1	69.6	56.7	16.48	3.17	1.62	5.56	7.54
T_9 (Control)	73.3	64.4	49.1	16.35	3.09	1.56	5.52	7.05
SEm±	0.67	0.70	0.73	0.09	0.07	0.02	0.23	0.04
CD (P=0.05)	2.0	2.1	2.2	NS	NS	0.05	NS	0.12

T_1, (RN), Recommended nitrogen 40 kg N/ha; T_2, (GM), green manure; T_3, GM + 25% RN; T_4, GM + 50% RN; T_5, (FYM) farmyard manure to supply 40 kg N/ha; T_6, FYM + 25% RN; T_7, FYM + 50% RN; T_8, FYM + GM; T_9, unfertilized control the recommended nitrogen (T_1). Head-rice recovery with green manuring (T_2) and different nutrient combinations (T_3, T_4 and T_6) was statistically at par with that of recommended nitrogen (T_1). The FYM when supplemented with 50% RN (T_7) or green manuring supplemented with FYM (T_8) had significantly higher head-rice recovery than that of RN, whereas FYM alone (T_5) had significantly lower head rice recovery than that of RN (T_1). The different nitrogen sources did not differ significantly in respect of minimum cooking time, water-absorption ratio and cooking coefficient. Elongation ratio of grains with different nutrient sources was statistically at par with recommended nitrogen. However, the highest elongation ratio was observed in FYM + 50% RN (T_7) and it was significantly more than GM+50% RN (T_4) and FYM + 25% RN (T_6). Grain protein content with green manuring (T_2) was statistically similar to that of RN (T_1). The grain protein content was significantly higher by 3.9 and 2.3% than the RN when FYM was supplemented with 50% RN (T_7) and green manuring (T_8), respectively. Significantly lower grain protein content than that of RN was observed with FYM (T_5) and FYM + 25% RN (T_6). The higher protein content and increased elongation ratio with organic manures might be owing to uninterrupted availability of N coupled with increased absorption and assimilation by plants (Rao *et al.,* 2006).

Soil organic carbon and available NPK

All the organic sources (FYM and green manure) alone or in integration improved the soil organic carbon (6.4–12.8%) as compared to chemical nitrogen fertilization after 2 crop seasons (Table 3). The highest soil-available nitrogen was observed in FYM + 50% RN T_7 and it was statistically at par with GM + 25% RN (T_3), GM + 50% RN (T_4) and FYM + 25% RN (T_6) and was significantly higher than rest of the treatments.

Table 3. Effect of nitrogen treatments on soil organic carbon and available nutrients in soil after 2 crop seasons

Treatment	Organic carbon (g/kg)	Available nutrients (kg/ha)		
		N	P	K
T_1 (RN)	4.7	182.4	18.1	188.9
T_2 (GM)	5.0	186.2	18.7	195.6
T_3 (GM + 25% RN)	5.0	191.5	18.6	194.1
T_4 (GM + 50% RN)	5.1	194.7	18.5	193.9
T_5 (FYM)	5.1	182.5	19.2	198.3
T_6 (FYM + 25% RN)	5.2	192.6	19.6	197.3
T_7 (FYM + 50% RN)	5.1	195.3	19.2	198.5
T_8 (FYM + GM)	5.3	190.2	19.1	197.6
T_9 (Control)	4.6	158.1	17.8	182.4
SEm±	0.1	1.4	0.3	0.7
CD (P=0.05)	0.3	4.2	0.9	2.1

Initial status of experimental site: Organic carbon 4.5 g/kg, available N, P and K 162.6, 17.1 and 185.7 kg/ha
T_1, (RN), Recommended nitrogen 40 kg N/ha; T_2, (GM), green manure; T_3, GM + 25% RN; T_4, GM + 50% RN; T_5, (FYM) farmyard manure to supply 40 kg N/ha; T_6, FYM + 25% RN; T_7, FYM + 50% RN; T_8, FYM + GM; T_9, unfertilized control

Table 4. Effect of nitrogen treatments on gross returns, net returns and benefit: cost ratio of basmati rice (mean over 2 years)

Treatment	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
T_1 (RN)	32,795	85,006	52,211	1.59
T_2 (GM)	37,450	84,883	47,433 (68,042)*	1.27 (1.82)*
T_3 (GM + 25% RN)	37,505	84,309	46,804	1.25
T_4 (GM + 50% RN)	37,573	86,319	48,746	1.30
T_5 (FYM)	33,950	73,926	39,976	1.18
T_6 (FYM +25% RN)	34,005	81,085	47,080	1.38
T_7 (FYM + 50% RN)	34,073	87,894	53,821	1.58
T_8 (FYM + GM)	38,850	87,783	48,933	1.26
T_9 (Control)	32,550	66,279	33,729	1.04

T_1, (RN), Recommended nitrogen 40 kg N/ha; T_2, (GM), green manure; T_3, GM + 25% RN; T_4, GM + 50% RN; T_5, (FYM) farmyard manure to supply 40 kg N/ha; T_6, FYM + 25% RN; T_7, FYM + 50% RN; T_8, FYM + GM; T_9, unfertilized control
Sale price, Basmati rice grain; 2700/q and straw; 40/q
*25% premium on organic produce

The soil-available phosphorus status was statistically at par among different FYM-based treatments and was slightly higher than the other treatments, which might be due to addition of P present in FYM. Hemalatha *et al.* (2000) reported increase in available P with green manuring. The soil-available potassium improved significantly with all the treatments than that of recommended nitrogen and that might be owing to reduction of K-fixation and solubilisation and release of fixed K. Roy *et al*. (2013) and Gour *et al.* (2015) also reported increased potassium status of soil with integration of organic manures and chemical fertilizer.

Economics

The cost of cultivation was higher in treatments, comprising green manure due to additional cost of raising the green-manure crop and its incorporation in soil. Chemical fertilizer was the most economical nutrient source in raising the basmati rice. Roy *et al*. (2013) also reported higher profit in rice with recommended chemical fertilizer as compared to its integration with organic sources. The gross and net returns were the highest where FYM was supplemented with 50% dose of recommended nitrogen. The benefit: cost ratio was the highest (1.59) in chemical fertilizer owing to its lowest cost to supply nutrients (Table 4). However, if 25% premium is given to the crop raised with green manure only (organic situations), then it gives the highest net returns and benefit: cost ratio (1.82).

The results of the field study showed that basmati rice can successfully be grown with green manuring only or by integration of FYM and reduced dose of chemical fertilizer. Though these are costly options than chemical fertilizer, these improve soil organic carbon and available N, P and K as compared with chemical fertilizer alone and contribute to agricultural sustainability.

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