Indian Journal of Agricultural Sciences **87** (10): 1377–83, October 2017/Article

Effect of different cropping systems and nutrient sources on growth, productivity and economics of direct seeded basmati rice (*Oryza sativa*)

RAKESH KUMAR VERMA[1], YASHBIR SINGH SHIVAY[2] and PRAKASH CHAND GHASAL[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Received: 30 June 2016; Accepted: 29 May 2017

ABSTRACT

A field experiment was conducted during rainy *(kharif)* seasons of 2014 and 2015 at New Delhi to evaluate the effects of cropping systems and nutrient sources on growth, root parameters, yield attributes, yields and economics of direct seeded basmati rice (*Oryza sativa*). On pooled average basis, the highest growth parameters, yield attributes, viz. effective tillers, spike length, grains/panicle and grain weight (g)/spike and yields were associated with inclusion of summer mungbean in the rice-based cropping systems. On pooled average basis, among the nutrient management strategies, 50% recommended dose of fertilizers (RDF) + 25% recommended dose of nitrogen (RDN) through vermicompost (VC) + biofertilizer was found to be best for most of the yield attributes, grain (3.72 t/ha) and straw (7.14 t/ha) yields and gross returns (105.14×10^3 ₹/ha) followed by 50% RDF + 25% RDN through leaf compost (LC) + biofertilizer. Similarly, the highest root growth length (4.93 cm/cm^3), root volume (16.41 cm^3) and root dry matter (4.87 g) were registered under treatment 50% RDF + 25% RDN through VC + biofertilizer followed by 50% RDF + 25% RDN through leaf compost (LC) + biofertilizer and then 100% RDF. A strong positive correlation (r^2=0.89–0.97) was also observed between yield attributes (effective tillers/m^2, grains/panicle, grain weight/panicle and panicle weight) and yield of direct seeded basmati rice. Application of 100% RDF proved better and accrued the highest net returns and B: C ratio (1.54). DSBR–wheat–mungbean or DSBR–cabbage–mungbean cropping system in conjunction with 50% RDF + 25% RDN through VC + biofertilizer or 50% RDF + 25% RDN through leaf compost (LC) + biofertilizer significantly improved growth, yield attributes, leading to enhanced productivity and profitability of rice.

Key words: Basmati rice, *BGA,* Leaf compost, Root parameters, Vermicompost

The major concerns with the sustainability of rice (*Oryza sativa* L.)-based cropping systems are yield stagnation (Busari *et al*. 2015), rapidly declining underground water table (Humphreys *et al.* 2010, Hira *et al.* 2004), soil health degradation (Bhandari *et al.* 2002) and environmental pollution (Singh *et al*. 2008). Excessive and indiscriminate use of nitrogenous-fertilizers resulted into leaching of nitrates which is responsible for the eutrophication and pollution of ground water. Judicious use of the fertilizers depending upon the soil test reports is the key to profitability of the rice-wheat cropping system (Bhatt 2013). Careful scientific management of diversified rice–wheat systems is considered answer to these problems (Khush 2004, Gangwar and Prasad 2005).

Looming water crisis, water-intensive nature of rice cultivation and escalating labour costs drive the search for alternative management methods to increase water productivity in rice cultivation. Direct seeded rice (DSR) has received much attention because of its low-input demand. Direct seeding rice, a common practice before 'Green Revolution' in India, is becoming popular once again because of its potential to save water and labour (Gupta *et al.* 2006). The area of direct seeded rice in India is 7.2 million ha. Thus, the direct seeded rice occupies 26% of the total rice area in south Asia. Productivity of direct seeded rice often reported to be comparable with conventional transplanting method (Gangwar *et al*. 2008).

The 'Green Revolution' in India has increased the yields tremendously, however, it served as a mixed blessing, as on one hand ambitious use of agrochemicals boosted the food grain production and on the other hand, it destroyed the agricultural ecosystem. No doubt, the use of chemical fertilizers is the quickest way of boosting crop production, but their increasing prices, soil health deterioration, sustainability and pollution considerations in general have led to renewed interest in the use of organic manures. This decline in soil fertility and productivity is attributed to the appearance of secondary and micronutrient deficiency as well as deteriorating soil physical conditions by long-term use of chemical fertilizers in imbalanced proportion giving more emphasis to the use of nitrogenous fertilizers. Strategic use of varied nutrient sources, including inorganic fertilizers, combined with increases in the plant diversity

[1]Ph D Student (e mail: sherawat90rakeshgmail.com), [2]Professor and Principal Scientist (e mail: ysshivay@iari.res.in), Division of Agronomy, IARI, New Delhi; [3]Scientist (Agronomy) (e mail: pcghasal@gmail.com), ICAR-Indian Institute of Farming systems Research, Modipuram.

aimed at expanding the functional roles of plants in agro-ecosystems will help to restore desired agro-ecosystem functions. Integrated nutrient management by ensuring an adequate and balanced supply of nutrients to plants can only help to attain major increase in productivity. The results of long-term fertilizer experiments revealed that sustainable production of any cropping system could be achieved only by maintaining a balance between supply and demand of nutrients by integration of inorganic, and organic sources of nutrients like farmyard manure, vermicompost, leaf compost, pressmud and crop residues (Murali and Setty 2000).

Integration of inorganic and organic manure provides balanced nutrition to crops and minimizes the antagonistic effects resulting from hidden deficiencies and nutrient imbalance. Biofertilizers are cultures of living microorganisms that are capable of fixing atmospheric N, solublize and mobilize the native soil P and K by release of certain organic acids (gluconic, lactic, citric, tartaric etc). Therefore, an attempt needs to be made to diversify the existing systems and reorientation of nutrient management strategies for increasing the productivity on the sustainable basis.

MATERIALS AND METHODS

A field experiment with direct seeded basmati rice was conducted during the rainy *(kharif)* season of 2014 and 2015 at ICAR-Indian Agricultural Research Institute, New Delhi (28°38' N and 77°10' E, 228.6 m above mean sea-level). The climate of above unit is semi–arid with dry hot summers and cold winters with an average annual rainfall of 650 mm, 80% of which is received through south-west monsoons during July–September. Soils are alluvium-derived sandy clay loam (typic Ustochrept) with 51.7% sand, 21.9% silt and 26.4% clay. The soil (0–30 cm layer) had pH 7.9 (1:2.5 soil: water ratio), Walkley–Black C (oxidizable-SOC) 0.49%, alkaline $KMnO_4$-oxidizable–N 209.7 kg/ha (Subbiah and Asija 1956), 0.5 M $NaHCO_3$-extractable P 15.3 kg/ha (Olsen *et al.* 1954), and 1 N NH_4OAc-extractable K 272.4 kg/ha (Hanway and Heidel 1952).

The experiment was laid-out in a strip-plot design and replicated thrice. Four cropping systems, viz. direct seeded basmati rice–wheat–fallow, DSBR–wheat–mungbean, DSBR–cabbage–mungbean and DSBR–cabbage–onion were assigned to vertical strips; and 4 nutrient sources, *viz.* control, 100% recommended dose of fertilizers (RDF) through fertilizers, 50% RDF + 25% recommended dose of nitrogen (RDN) through leaf compost (LC) + biofertilizers, 50% RDF + 25% RDN through vermicompost (VC) + biofertilizers were assigned to horizontal strips. The RDF of rice was 120:60:60 kg N:P_2O_5:K_2O/ha. The vermicompost and leaf compost was applied before sowing of crops based on the nitrogen equivalent basis and requirement of crop in respective treatments. Allocations of the treatments were done by the randomization following Fisher and Yates random number tables. One third of N and full dose of P and K were applied as basal. Remaining N to be applied by fertilizer was applied in two equal splits after first irrigation and at tillering stage in rice. The application of blue green algae (BGA) was done 25 day after sowing of the crop in the respective treatments. Rice seeds were sown through zero-till seed drill machine with a row spacing of 22.5 cm, using seed rate of 60 kg/ha on 24th June and 27th June during 2014 and 2015, respectively. The plot size was 5.0 m × 3.0 m for each treatment. Rice crop was grown as per the standard recommended package of practices and was harvested in the month of October during both the years of experimentation.

Plant height of rice was measured from the base of the plant at ground surface to the tip of the tallest leaf blade using a standard meter scale. Tillers number was noted by counting from the sampling unit at harvesting stage. For total dry matter accumulation at 60 days after sowing (DAS) and harvesting stage, plants from one meter square area were harvested then air dried and further dried in a hot air oven at 60°±2°C till constant weight was obtained. Dry weight was recorded and was expressed in g/m^2. Leaf area (cm^2) measured using 'Leaf Area Meter' {LI–COR Model L1–3000, Lambda Instrument Corporation, Nebraska, USA} from the plants selected for recording the dry matter accumulation. The leaves were separated from the stem and cleaned with tap water and with de–ionized water and then dried with tissue paper. The leaf area was expressed in cm^2 per plant. Leaf area index is expressed as the ratio of leaf surface (one side only) to the ground area occupied by the plant.

$$\text{LAI} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

Relative growth rate (RGR) expresses the dry weight increase in a time interval in relation to initial weight. It is calculated from the measurements taken at times T_1 and T_2. In fact, RGR value is the slope of the line when Log w is plotted against T. RGR was calculated using following expression:

$$\text{Mean RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \text{ mg/g/day}$$

where, W_1 and W_2 are the dry weight values at time T_1 and T_2, respectively. T_1 and T_2 are time in days.
The crop growth was calculated using following formula:

$$\text{Mean CGR} = \frac{W_2 - W_1}{T_2 - T_1} \text{ g/day/m}^2$$

Net assimilation rate is the net gain of assimilate per unit leaf area time. It represents the photosynthetic efficiency of leaves. The following formula was used to calculate the NAR.

$$\text{Mean NAR} = \frac{(W_2 - W_1)(\text{In } LA_2 - \text{In } LA_1)}{(T_2 - T_1)(LA_2 - LA_1)} \text{ g/day/m}^2$$

where, W_2 and W_1 are dry weights recorded at times T_2 and T_1, respectively. LA_2 and LA_1 are the leaf area values recorded at times T_2 and T_1.

Root samples were taken from third row of the crop at 50% flowering stage in rice. A root auger of 8.0 cm diameter and 15 cm height (core volume = 754.28 cm^3) was used to take root samples up to 0-15 cm depth of soil profile. The roots were washed properly by putting roots on container with sieves to prevent loss of fine roots during washing and immediately kept in refrigerator at 4^0C. Root parameters like root length and root volume using root scanner were measured (Epson expression 1640XL). After scanning, the root samples were dried at 60^0C for 48 hrs for recording root dry weight.

Ten panicles of rice were randomly selected at the time of harvest. The panicle length was measured from the neck to the tip of the panicle. The mean length of panicle was computed and was expressed in cm. Ten panicles of rice were randomly selected at the time of harvest and their weight was taken. Mean weight of panicles was computed and was expressed in grams. Ten panicles of rice were randomly selected at the time of harvest and were threshed manually. The grains so obtained were cleaned and counted manually. The mean value of grains per panicle were calculated and expressed as number of grains per panicle. The 1000 grains taken from sampled panicles were first counted by a seed counter and then weighed to compute the test weight.

After harvesting, threshing, cleaning and drying, the grain yield of rice was estimated at 14% moisture content. Likewise, straw yield was recorded by subtracting grain yield from the total biomass yield. Yield was expressed in t/ha. Gross and net returns were calculated based on the grain and straw yield and their prevailing market prices of rice in respective seasons. Benefit–to–cost ratio (B:C) was calculated by dividing the net returns from total cost of cultivation. The B:C ratio was calculated by using following expression: net returns (₹/ha)/cost of cultivation (₹/ha). The data obtained from study for two years were analysed statistically using the F–test, as per the procedure given by Gomez and Gomez (1984). LSD values at P = 0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Growth parameters and crop growth indices

Growth attributes, viz. plant height, tillers/m^2, leaf area index (LAI) and dry matter accumulation (DMA) (g/m^2) of direct seeded basmati rice (DSBR) were significantly influenced by cropping systems and nutrient sources (Table 1). In general, all growth parameters increased with the advancement of the crop growth stages. No significant variations among different cropping systems were recorded

Table 1 Effect of cropping systems and nutrient sources on plant height, tillers, dry matter accumulation (DMA), leaf area index (LAI), mean crop growth rate (CGR), mean relative growth rate (RGR) and mean net assimilation rate (NAR) of direct seeded *basmati* rice (pooled data of 2 years)

Treatment	Plant height (cm)	Tillers/m^2 (Nos.)	DMA (g/m^2)		LAI			Mean CGR (g/m^2/day)			Mean RGR (mg/g/day)		Mean NAR (g/m^2 leaf area/day)	
			60 DAS	At harvest	30 DAS	60 DAS	90 DAS	0-30 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Cropping systems														
DSBR–wheat	96.0	291.7	263.0	1008.9	0.75	4.05	3.27	1.68	7.1	22.4	55.5	41.8	3.8	6.3
DSBR–wheat–moongbean	97.0	296.5	267.6	1011.7	0.78	4.39	3.28	1.75	7.2	22.5	55.1	41.6	3.6	6.0
DSBR–cabbage–moongbean	96.9	295.8	266.9	1021.5	0.76	4.37	3.30	1.76	7.1	22.6	54.7	41.8	3.5	6.0
DSBR–cabbage–onion	96.2	293.1	263.9	1012.1	0.74	4.09	3.27	1.75	7.05	22.40	54.2	42.2	3.7	6.3
SEm±	1.22	8.20	6.01	29.65	0.031	0.164	0.085	0.087	0.21	0.593	1.88	1.12	0.19	0.22
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrients sources														
Control	85.1	205.3	203.5	708.1	0.57	3.09	2.02	1.23	5.6	14.8	57.7	38.4	3.9	6.2
100% RDF through fertilizers	100.5	322.7	283.6	1111.6	0.83	4.60	3.63	1.96	7.5	24.9	52.6	43.1	3.5	6.2
50% RDF + 25% RDN-LC + bio.	98.7	321.8	283.1	1111.0	0.81	4.46	3.66	1.86	7.6	25.0	54.5	43.1	3.6	6.3
50% RDF + 25% RDN-VC + bio.	101.7	327.3	291.2	1123.5	0.82	4.75	3.81	1.89	7.9	25.2	54.6	42.6	3.6	6.0
SEm±	2.52	10.80	7.91	34.17	0.028	0.172	0.146	0.068	0.255	1.32	1.60	2.13	0.14	0.54
CD (P=0.05)	8.60	37.29	27.33	118.22	0.101	0.594	0.506	0.235	0.885	4.55	NS	NS	NS	NS

DSBR, Direct seeded basmati rice; RDF, Recommended dose of fertilizers; RDN, Recommended dose of nitrogen; LC, Leaf compost; VC, Vermicompost, bio, Biofertilizers; DAS, Days after sowing in plant height, tillers/m^2, LAI and DMA g/m^2 at all stages. Numerically better growth parameters were recorded where summer mungbean was added compared to other cropping systems. This could be due to the beneficial effect of leguminous crop (mungbean) on soil properties by adding a significant amount of organic matter and available nitrogen. The mean values of crop growth indices, viz. CGR, RGR and NAR were also not significantly influenced under different cropping systems during the experimentation (Table 1). The highest value of crop growth indices i.e. CGR and NAR were recorded at 60-90 DAS and mean RGR at 30-60 DAS.

Application of different nutrient sources significantly increased the plant height, tillers, DMA and LAI of DSBR at all the stages over control. Among the different nutrient sources, 50% RDF + 25% RDN-VC + biofertilizer registered the highest values of plant height, tillers, DMA and LAI during the study. All nutrient management strategies remained statistically at par with respect to given growth parameters except control. The beneficial role of organic manures in crop production has been established since long. The soil organic matter is considered to be elixir of plant life by virtue of being a source of almost all the essential macro and micronutrients. At 0-30 DAS, significantly the highest values of mean CGR were observed with the application of 100% RDF and at 30-60 DAS and 60-90 DAS with 50% RDF + 25% RDN-VC + bio fertilizer. The values of mean RGR and NAR were found statistically identical among different nutrient sources between 30–60 DAS and 60–90 DAS. Vermicompost and leaf compost added a significant amount of NPK in the soil, besides supplying other essential micronutrients to the soil. In association with soil microorganisms, organic manures are known to help in synthesis of certain phytohormones and vitamins which promote the growth and development of crops. Similar results were obtained by Sharma *et al.* (2015).

Root parameters

The root length density (cm/cm^3), root volume (cm^3) and root dry matter (g) did not vary significantly under different cropping systems during the study (Table 2). Numerically maximum root length density was recorded under DSBR-wheat-mungbean and DSBR-cabbage-mungbean cropping systems. Similarly, root volume and root dry matter was found numerically the highest in DSBR-wheat-mungbean and DSBR–cabbage–mungbean cropping system, respectively.

Application of different nutrient sources improved significantly root length density, root volume and root dry matter in comparison to control (Table 2). Root length density, root volume and root dry matter was recorded the highest with application of 50% RDF + 25% RDN through VC + biofertilizer treatment which was found at par with 50% RDF + 25% RDN through LC + biofertilizer and 100% RDF through fertilizers.

Yield attributes and yields

The different cropping systems and nutrient sources had marked influence on yield attributes and yields of DSBR (Tables 2 & 3). Though, no significant variation was observed in yield attributes and yields of DSBR

Table 2 Effect of cropping systems and nutrient sources on root parameters in 754.28 cm^3 soil volume and yield attributes of direct seeded *basmati* rice (pooled data of 2 years)

Treatment	Root length density (cm/cm^3)	Root volume (cm^3)	Root dry matter (g)	Effective tillers/m^2 (Nos.)	Panicle length (cm)	Panicle weight (g)	Grains/ panicle (Nos.)	Grain weight/ panicle (g)	1000-grain weight (g)
Cropping systems									
DSBR–wheat	4.54	13.89	4.01	229.0	24.7	1.91	103.2	1.84	23.6
DSBR–wheat–mungbean	4.58	14.82	4.10	230.9	24.8	1.92	105.0	1.85	23.9
DSBR–cabbage–mungbean	4.55	14.76	4.12	230.1	24.9	1.93	105.6	1.85	24.3
DSBR–cabbage–onion	4.54	14.20	4.06	229.1	24.9	1.91	103.8	1.84	23.9
SEm±	0.084	0.360	0.103	4.58	0.14	0.026	2.55	0.012	0.28
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrients sources									
Control	3.73	10.13	2.17	145.8	23.4	1.74	89.1	1.66	22.5
100% RDF through fertilizers	4.77	15.33	4.59	256.1	25.3	1.98	108.6	1.91	24.4
50% RDF + 25% RDN-LC + bio.	4.79	15.79	4.67	256.5	25.2	1.98	109.4	1.90	24.4
50% RDF + 25% RDN-VC+ bio.	4.93	16.41	4.87	260.7	25.5	1.98	110.6	1.92	24.6
SEm±	0.107	0.545	0.161	7.60	0.44	0.045	1.61	0.032	0.43
CD (P=0.05)	0.369	1.888	0.556	26.28	1.53	0.155	5.54	0.112	1.47

DSBR, Direct seeded basmati rice; RDF, Recommended dose of fertilizers; RDN, Recommended dose of nitrogen; LC, Leaf compost; VC, Vermicompost; bio, Biofertilizers under different cropping systems. Higher numerical value of panicle weight (g), grains/panicle (Nos.), grain weight/panicle (g) and 1,000-grain weight (g) were recorded with DSBR–wheat–mungbean and DSBR-cabbage-mungbean compared to remaining cropping systems. Grain and straw yields was found identical among different cropping systems. Although, numerically highest grain, straw, biological yields and harvest index (HI) was recorded in DSBR-cabbage-mungbean and DSBR-wheat-mungbean. It might be due to the inclusion of mungbean in the cropping systems which has marked improvement in soil fertility status. It is well documented that inclusion of pulses (mungbean) leave behind substantial amount of N in soil after their harvest, helps in efficient utilization of native phosphorus as well as solubilization of various forms of phosphorus due to secretion of certain acids and also adds significant amount of organic residues to the soil in the form of root biomass and leaf litter.

All the nutrient management strategies produced significantly the highest panicle weight (g), grains/panicle (Nos.), grain weight/panicle (g) and 1000-grain weight (g), grain, straw and biological yields of DSBR over control (Tables 2 & 3). DSBR responded better to organic source and biofertilizer, whereby application of 50% RDF + 25% RDN-VC + biofertilizer gave significantly the highest yield attributes and grain, straw and biological yields of DSBR over control and found statistically similar to remaining nutrient management strategies. On pooled average basis, the application of 50% RDF + 25% RDN through VC + biofertilizer registered an increase of 66.3% over the control. Similarly, application of 50% RDF + 25% RDN through LC + biofertilizer also increased the grain yield of DSBR to the tune of 64.9% over the control. Organic carbon in vermicompost releases the nutrients slowly and steadily into the soil solution and enables the plants to absorb these nutrients. The multiple effects of vermicompost influence the growth and yield of crops. Vermicompost have low C:N ratio and thus availability of nutrients is higher, which resulted in to higher absorption of nutrients and consequently higher yields. The maximum yield with application of 50% RDF + 25% RDN-VC + biofertilizer could be attributed as a result of higher uptake and recovery of applied nutrients. This might be due to better root growth and proliferation and also opportunity to extract water and nutrients both from larger soil profile area, which in turn must have improved synthesis and translocation of metabolites to various reproductive structures of rice plant and better distribution of it into grain would always results in higher grain yield. This result corroborated with the findings of Jana (2012). Ghanshyam *et al.* (2010) observed that application of FYM and vermicompost being at par with each other significantly improved the available N and P status of soil over non organic manure application. Barik and gulati (2009) reported significantly higher number of effective tillers/m^2 and grain and straw yield in case of 50% RDF + vermicompost @ 10 tonnes/ha in comparison to 100% RDF. These results were also in conformity with the findings of Davari and Sharma (2010) and Garai *et al.* (2014). Strong positive correlation was found among yield attributes and yield of direct seeded basmati rice (Fig 1).

Table 3 Effect of cropping systems and nutrient sources on yields, harvest index and economics of direct seeded *basmati* rice (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Total cost ($\times 10^3$ `/ha)	Gross returns ($\times 10^3$ `/ha)	Net returns ($\times 10^3$ `/ha)	B:C ratio
Cropping systems								
DSBR–wheat	3.27	6.46	9.72	33.30	46.10	92.60	46.46	1.02
DSBR–wheat–mungbean	3.36	6.54	9.89	33.81	46.10	94.82	48.75	1.08
DSBR–cabbage–mungbean	3.35	6.53	9.87	33.85	46.10	94.73	48.62	1.07
DSBR–cabbage–onion	3.33	6.51	9.83	33.65	46.10	94.13	47.96	1.06
SEm±	0.059	0.115	0.138	0.535		1.501	1.503	0.036
CD (P=0.05)	NS	NS	NS	NS		NS	NS	NS
Nutrients sources								
Control	2.24	4.71	6.94	32.15	34.05	63.90	29.86	0.88
100% RDF through fertilizers	3.67	7.09	10.76	34.15	40.97	103.69	62.76	1.54
50% RDF + 25% RDN-LC + bio.	3.67	7.09	10.75	34.05	55.11	103.54	48.36	0.88
50% RDF + 25% RDN-VC+ bio.	3.72	7.14	10.87	34.3	54.24	105.14	50.84	0.94
SEm±	0.071	0.1355	0.1665	0.605		1.779	1.782	0.061
CD (P=0.05)	0.2445	0.4675	0.575	2.095		6.153	6.151	0.22

DSBR, Direct seeded basmati rice; RDF, Recommended dose of fertilizers; RDN, Recommended dose of nitrogen; LC, Leaf compost; VC, Vermicompost, bio, Biofertilizers

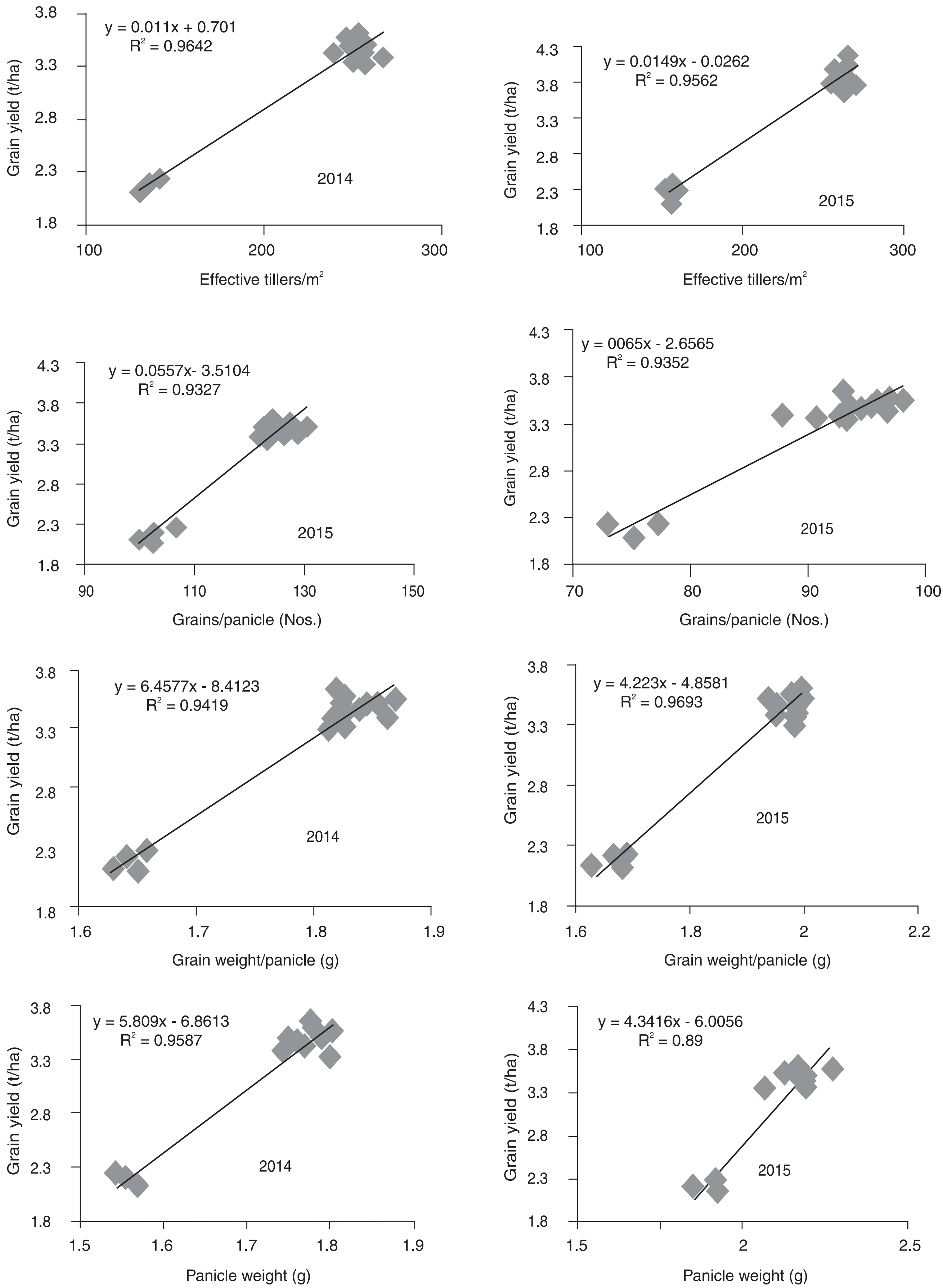

Fig 1 Correlation of rice grain yield with yield attributes

Economics

Economics of direct seeded basmati rice was significantly influenced by different cropping systems and nutrients management strategies (Table 3). Cost of cultivation was found similar among different cropping systems. Gross returns, net returns and B:C ratio was found at par among different cropping systems. The highest net returns and B: C ratio was obtained under DSBR-wheat-mungbean and DSBR-cabbage-mungbean in comparison to the rest cropping systems.

Cost of cultivation was recorded higher where organic and inorganic sources of nutrients were applied. Significantly the highest gross returns (105.14×10^3 ₹/ha) were registered with the application of 50% RDF + 25% RDN-VC + biofertilizer. The significantly highest net returns (62.76×10^3 ₹/ha) and B:C ratio (1.54) was recorded with application of 100% RDF through fertilizers. However, the treatments 50% RDF + 25% RDN-LC + biofertilizer and 50% RDF + 25% RDN-VC + biofertilizer remained statistically similar in terms of net returns and B:C ratio.

Based on results of present study, it can be concluded that inclusion of leguminous crop in rice–based cropping systems increases growth, yield attributes, yield and profit of direct seeded basmati rice in IGPs. Integrated use of vermicompost/leaf compost and inorganic nutrient in conjunction with biofertilizers also improves above and below ground crop growth of direct seeded basmati rice that improve the productivity and profitability of the crop.

REFERENCES

Barik T and Gulati J M L. 2009. Use of vermicompost in field crops and cropping systems – A review. *Agricultural Review* **30**(1): 48–55.

Bhandari A L, Ladha J K, Pathak H, Padre A T, Dawe D and Gupta R K. 2002. Yield and soil nutrient changes in a long term rice–wheat rotation in India. *Soil Science Society of America Journal* **66**: 162–70.

Bhatt R. 2013. Soil test based fertilization to improve production of oilseed crops in Kapurthala district of Punjab. *International Journal of Science and Environment Technology* **2**(3): 521–6.

Busari M A, Kukal S S, Kaur A, Bhatt R and Dulazi A A. 2015. Conservation tillage impacts on soil, crop and the environment. *International Soil and Water Conservation Research.*

Davari M R and Sharma S N. 2010. Effect of different combinations of organic materials and biofertilizers on productivity, grain quality and economics in organic farming of basmati rice (*Oryza sativa L.). Indian Journal of Agronomy* **55**(4): 290–4.

Gangwar B and Prasad K. 2005. Cropping system management for mitigation of second generation problems in agriculture. *Indian Journal of Agriculture Sciences* **75**(2): 65–78.

Gangwar K S, Tomar O K and Pandey D K. 2008. Productivity and economics of transplanted and direct-seeded rice (*Oryza sativa*)-based cropping systems in Indo-Gangetic plains. *Indian Journal of Agricultural Sciences* **78**: 655–8.

Garai T K, Data J K and Mondal N K. 2014. Evaluation of integrated nutrient management on boro rice in alluvial soil and its impacts upon growth, yield attributes, yield and soil nutrient status. *Archives of Agronomy and Soil Science* **66**(1): 1–4.

Ghanshyam, Kumar R and Jat R K. 2010. Productivity and soil fertility as affected by organic manures and inorganic fertilizers in mungbean (*Vigna radiata)* system. *Indian Journal of Agronomy* **55**(1): 16–21.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research,* edn 2. An International Rice Research Institute Book. Wiley-Inter-Science Publication, John Wiley & Sons, New York.

Gupta R K, Ladha J K, Singh S, Singh R G, Jat M L, Saharawat Y, Singh V P, Singh S S, Singh G, Sah G, Ghatala M, Sharma R K, Gill M S, Alam M, Mujeeb H, Rahman U R, Singh U P, Mann R A, Pathak H, Chauhan B S, Bhattacharya P and Malik R K. 2006. Production technology for direct seeded basmati rice. Technical Bulletin 8, *Rice-Wheat Consortium for the Indo-Gangetic Plains,* New Delhi, India, p 16.

Hanway J J and Heidel H. 1952. *Soil Analysis Methods as Used in Iowa State College Soil Testing Laboratory*. Bulletin 57, Iowa State College of Agriculture, Iowa, USA, pp 131.

Hira G S, Jalota S K and Arora V K. 2004. Efficient management of water resources for sustainable cropping in Punjab. Research Bulletin 20, Department of Soils, Punjab Agricultural University, Ludhiana.

Humphreys E, Kukal S S, Christen E W, Hira G S, Singh B, Yadav S and Sharma R K. 2010. Halting the ground water decline in north-west India-which crop technologies will be winners? *Advances of Agronomy* **109**: 156–99.

Jana K. 2012. Effect of nitrogen levels and weed management practices on grain yield of aerobic rice cultivation system. *Green Farming* **3**(6): 687–9.

Khush G S. 2004. Harnessing science and technology for sustainable rice-based production systems. Proceedings of FAO Rice Conference 'Rice is life'. *International Rice Communication, News Letter* **53**: 17–23.

Murali M K and Setty R A. 2000. Effects of levels of NPK, vermicompost and growth regulators (Triacontanol) on growth and yield of scented rice. *Mysore Journal of Agricultural Sciences* **34**(4): 335–9.

Olsen R, Cole C V, Watanabe F S and Dean L A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular-939, United States Department of Agriculture, Washington DC, USA.

Sharma S K, Rana S S, Subehia S K and Negi S C. 2015. Production potential of rice-based cropping sequences on farmers' fields in low hills of Kangra district of Himachal Pradesh. *Himachal Journal of Agricultural Research* **41**(1): 20–4.

Singh B, Shah Y H, Singh Y and Buresh R J. 2008. Crop residue manaement for low land rice-based cropping systems in Asia. *Advances in Agronomy* **98**: 117–99.

Subbiah B V and Asija G L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**(8): 259–60.