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Research Paper

Productivity and profitability of wheat (*Triticum aestivum*) as influenced by different cropping systems and nutrient sources

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2014–15 and 2015–16 at New Delhi, to evaluate the effects of cropping systems and nutrient sources on yield attributes, yields and economics of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol]. Of the tested cropping systems, direct-seeded basmati rice (DSBR) (*Oryza sativa* L.)–wheat–mungbean [*Vigna radiata* (L.) R. Wilczek] system exhibited the highest values of yield attributes, viz. effective tillers, grains/spike and 1,000-seed weight which led to the highest grain yield (4.44 t/ha) and wheat equivalent yield (WEY) (11.7 t/ha). Among the nutrient sources, application of 50% recommended dose of fertilizers (RDF) + 25% recommended dose of nitrogen (RDN) through vermicompost (VC) + bio-fertilizer resulted in the highest yield attributes, grain (4.76 t/ha) and straw (6.86 t/ha) yields and gross returns (105.07×10^3 ₹/ha) followed by 50% RDF + 25% RDN through leaf compost (LC) + bio-fertilizer. A strong positive correlation ($r^2 = 0.69–0.97$) was also observed between yield attributes (effective tillers/m^2 and grains/spike) and yield of wheat. The uptake of nitrogen (N), phosphorus (P) and potassium (K) in grain and straw of wheat remained statistically identical in DSBR–wheat–fallow and DSBR–wheat–mungbean systems. Application of 50% RDF + 25% RDN-VC + bio-fertilizer registered significantly the highest uptake of N, P and K in both grain and straw of wheat and found on a par with 50% RDF + 25% RDN-LC + bio-fertilizer and 100% RDF. On the basis of net returns an application of 100% RDF was found superior to all the treatments. Therefore, DSBR–wheat–mungbean cropping system in conjunction with 50% RDF + 25% RDN-VC + bio-fertilizer or 50% RDF + 25% RDN-LC + bio-fertilizer significantly improved the yield attributes, leading to higher productivity and profitability of wheat over the control.

Key words : Bio-fertilizer, Cropping systems, Leaf compost, Productivity, Vermicompost, Wheat

Rice–wheat cropping system is the major cropping system, is occupying nearly 13.5 million ha of Indo-Gangetic Plains (IGP) of South Asia covering Pakistan, India, Bangladesh and Nepal (Ladha *et al.,* 2003). These crops contribute more than 80% of the total cereal production and are critically important for employment and food security of hundreds of millions of rural families. The demand of these two cereals is expected to grow between 2% and 2.5% per annum until 2020 (Gupta and Seth, 2007). In India, wheat is the second most important cereal crop after rice, grown under sub-tropical environment covering an area of 29.9 million ha. Total production of wheat in India is 95.8 million tonnes, with a productivity of 2.9 t/ha (Economic Survey GoI, 2014–15). The productivity and sustainability of wheat threatened due to inefficient use of inputs (fertilizer, water, labour), increasing scarcity of resources, changing climate, emerging energy crisis and rising fuel prices, rising cost of cultivation and emerging socio-economic changes such as urbanization, migration of labour, preference of non-agricultural work, concerns about farm-related pollution (Ladha *et al.*, 2009). This has led to the decline in system productivity, particularly in the high-productive Northern zone of India, depleting groundwater resources in tube-well irrigated areas (Gupta *et al.,* 2006).

Rice-based crop production systems, viz. rice–wheat, rice–rice and rice–rice–fallow, are the most dominant crop sequences in the country. Continuous cultivation of rice alone or rice–wheat for longer periods leads to low system productivity. Inclusion of crops like oilseeds, pulses, vegetables and fodder crops will improve the economic condition of small and marginal farmers owing to higher price and/or higher volume of their main and by-products

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(Sharma *et al*., 2007).

Current nutrient-management strategies aim to deliver soluble chemical fertilizers directly to crops and have uncoupled carbon, nitrogen and phosphorus cycles in space and time. As a result, agricultural ecosystems are maintained in a state of nutrient saturation and are inherently leaky because chronic surplus additions of nitrogen and phosphorous are required to meet yield goals. However, it is not possible to supply all the nutrient requirements of crops wholly through organic manures, thus there is a need to have a relook on the issue as whole, in which use of inorganic fertilizers and organic manures are used in integrated mode. Integrated nutrient management by ensuring an adequate and balanced supply of nutrients to plants can only help to attain major increment and stability in productivity. The results of long-term fertilizer experiments indicated that sustainable production of any cropping system could be achieved only by maintaining a balance between supply and demand of nutrients by integration of inorganics and organic sources of nutrients, viz. farmyard manure, vermicompost, leaf compost, pressmud and crop residues.

Addition of organics to the soil increase the organic matter which provides the carbon and energy source for soil microbes and earthworms, reducing the hazard of erosion, supplies adequate and balance nutrition, enhance cation-exchange capacity (CEC), maintains lower bulk density, enhance carbon sequestration and lower down the negative environmental threats. Bio-fertilizers are cultures of living microorganisms that are capable of fixing atmospheric N, solubilize and mobilize the native soil P and K by release of certain organic acids (gluconic, lactic, citric, tartaric etc). Therefore, an attempt was made to diversify the existing cropping systems and reorientation of nutrient-management strategy for enhancing the productivity and profitability of wheat on the sustainable basis.

MATERIALS AND METHODS

A field experiment with wheat was conducted during the winter (*rabi*) season of 2014–15 and 2015–16 at research farm of ICAR-Indian Agricultural Research Institute, New Delhi (28°38' N, 77°10' E, 228.6 m above mean sea-level). The climate of site 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 (0–15 cm layer) had *p*H 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).

Two cropping systems, viz. DSBR–wheat-fallow and DSBR–wheat–mungbean were assigned to vertical strips; and 4 nutrient sources, viz. control (no manure and fertilizer), 100% recommended dose of fertilizers (RDF) , 50% RDF + 25% recommended dose of nitrogen (RDN) through leaf compost (LC) + bio-fertilizers, 50% RDF + 25% RDN through vermicompost (VC) + bio-fertilizers were assigned to horizontal strips. The experiment was laidout in a strip-plot design, replicated thrice. The rice crop was sown in June; wheat crop in November and mungbean in April during both the years. After harvesting of rice, pre-sowing irrigation was given and the field was harrowed, cultivated and levelled. Sowing of wheat was done at a row spacing of 22.5 cm in lines with a tractor-driven sowing machine. The seed rate of wheat used for sowing was 100 kg/ha. The RDF for wheat was 120 : 60 : 60 kg N : P_2O_5 : K_2O/ha. The vermicompost and leaf compost were 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 was applied basal. Remaining N fertilizer was applied in 2 equal splits-after first irrigation and at tillering stage in wheat. Seeds of wheat were treated with *Azotobacter* in respective treatments at the time of sowing. The plot size was 5.0 m × 3.0 m for each treatment. Irrigation water was applied at 20–25 days intervals during whole season. Wheat crop was grown as per the standard recommended package of practices and was harvested in the first week of April in both the years.

Ten spikes of wheat were randomly selected at harvesting. The spike length was measured from the neck to the tip of the spikes. The mean length of spike was computed and expressed in cm. Ten spikes of wheat were randomly selected at harvesting and their weight was taken. Mean weight of spike was computed and was expressed in g. Also, 10 spikes of wheat were randomly selected at harvesting and were threshed manually. The grains obtained from the 10 random spikes and grains were cleaned and counted manually. The mean value of grains/spike were calculated and expressed as number of grains/spike. The 1,000-grains taken from sampled spikes were first counted by a seed counter and then weighed to compute the test weight.

Plant samples of grains as well as straw of wheat crop collected at harvesting were dried in hot air oven at 60 ± 2°C for 48 h. The oven-dried samples were ground to pass through 40 mesh-sieve in a Macro-Wiley Mill. Nitrogen was estimated by modified Kjeldhal method (Jackson, 1967), P concentration by Vanado-molybdophosphoric yellow colour method (Jackson, 1967) and K concentration by Flame Photometer method (Jackson, 1967). The uptake of nutrients was computed by multiplying the concentrations with dry weight of the respective plant parts.

After harvesting, threshing, cleaning and drying, the grain yield of wheat 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 wheat in respective seasons. Benefit: cost ratio was calculated by dividing the net returns from total cost of cultivation. The data obtained from the study for 2 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

Yield attributes and yield

Two-year mean data on yield attributes, yield of wheat between DSBR–wheat-fallow and DSBR–wheat–mungbean systems did not differ significantly. However, relatively higher values were recorded in DSBR–wheat–mungbean than DSBR–wheat–fallow system, which was 3.25% higher over DSBR–wheat–fallow system (Table 1). This could be because of beneficial effect received owing to inclusion of mungbean in the cropping systems which added a significant amount of biomass and nitrogen in the soil. Furthermore, the results pertaining to system productivity in terms of wheat-equivalent yield (WEY) of the cropping systems indicated that significantly highest WEY was recorded in DSBR–wheat–mungbean (20.6% higher) compared to DSBR–wheat–fallow system. Such increase in system productivity was owing to inclusion of mungbean in the cropping system which was highly remunerative. Among the tested nutrient sources, application of 50% RDF + 25% RDN-VC + bio-fertilizer resulted in significantly highest number of effective tillers/m^2, grains/spike and 1,000-grain weight and found at par with other nutrient sources except the control. This may be attributed to higher availability of nutrients in vermicompost, increased availability of both the native and applied nutrients and better source and sink relationship that contributed to better dry-matter production of crops leading to the production of favourable yield components. The enhanced yield components might also be owing to the increased growth and leaf-area index (LAI), leading to higher photosynthetic rate and accumulation of more assimilates which in turn increased the sink size. As a result, almost all yield attributes of crop resulted into significant im-

Table 1. Effect of cropping systems and nutrient sources on yield attributes, yields, system productivity and economics of wheat (pooled data of 2 years)

Treatment	Effective tillers/m^2	Grains/ spike	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	System productivity (WEY t/ha)	Cost of cultivation (×10^3₹/ha)	Gross returns (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit: Cost ratio
Cropping systems											
DSBR–wheat	388.9	44.5	43.5	4.30	6.21	10.51	9.7	35.08	95.01	59.93	1.83
DSBR–wheat–mungbean	394.5	44.5	43.6	4.44	6.47	10.90	11.7	35.08	98.40	63.32	1.93
SEm±	10.75	1.38	0.75	0.149	0.205	0.291	0.1	–	2.713	2.713	0.083
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.6	–	NS	NS	NS
Nutrient sources											
Control	352.8	37.8	40.7	3.58	5.22	8.80	7.9	23.04	79.45	56.37	2.44
100% RDF	400.2	45.8	44.6	4.54	6.61	11.15	11.5	29.93	100.62	70.65	2.36
50% RDF + 25% RDN-LC + bio.	403.2	46.1	43.9	4.60	6.65	11.26	11.5	44.10	101.69	57.59	1.30
50% RDF + 25% RDN-VC + bio.	410.6	47.5	45.0	4.76	6.86	11.62	11.9	43.23	105.07	61.84	1.43
SEm±	7.18	0.78	0.57	0.088	0.118	0.178	0.2	–	1.659	1.659	0.05
CD (P=0.05)	24.86	2.68	1.98	0.304	0.409	0.616	0.5	–	5.741	5.741	0.173

DSBR, Direct-seeded basmati rice; RDF, recommended dose of fertilizers; RDN, recommended dose of nitrogen; LC, leaf compost; VC, vermicompost; Bio, bio-fertilizers; RDF (kg/ha)=120 N : 60 P : 60 K for wheat; RDF (kg/ha)=15 N : 30 P : for mungbean provement because of to integration of organic sources of nutrient with fertilizers.

Wheat grain, straw and biological yields were significantly higher with the application of different nutrient sources than the control (Table 1). Non-significant variation was observed in grain yield of wheat among 50% RDF + 25% RDN-VC + bio-fertilizer, 50% RDF + 25% RDN-LC + bio-fertilizer and 100% RDF. The application of 50% RDF + 25% RDN-VC + bio-fertilizer exhibited an increase of 32.95% grain yield over the control. Similarly, an application of 50% RDF + 25% RDN-LC + bio-fertilizer also increased the grain yield of wheat to the tune of 29.6% in comparison to the control. The straw and biological yields were the highest with the application of 50% RDF + 25% RDN-VC + bio-fertilizer followed by 50% RDF + 25% RDN-LC + bio-fertilizer and the lowest with the control. Furthermore, the WEY was recorded significantly highest with the application of 50% RDF + 25% RDN-VC + bio-fertilizer (50.6%), followed by 50% RDF + 25% RDN-LC + bio-fertilizer (45.6%) over the control. The different nutrient sources could not bring any marked variation in harvest index of wheat.

The integrated use of organic and inorganic source of nutrients might have supplied readily available nutrients to crop which resulted in greater assimilation, production and partitioning of dry- matter yield. The considerable improvement in grain yield owing to application of organic source along with fertilizers might be attributed to the positive effect on yield attributes and cumulative effect of yield attributes mainly responsible for higher productivity with the application of organic sources. Stimulated vegetative growth of wheat at latter stages, accounted to adequate availability and prolonged supply of macro and micronutrients in treatments receiving 50% RDF + 25% RDN-VC + bio-fertilizers fertilizer manifested itself in increased number of effective tillers, grains/spike and 1,000-grain weight. In addition, the presence of plant growth-promoting substances such as plant growth hormones and humic acids in vermicompost has also been suggested as a possible factor contributing to increased yield (Taleshi *et al.* 2011). Kandil *et al*. (2011) reported that inoculation with *Azotobacter* in wheat resulted in higher plant growth, yield attributes and yield compared to non-inoculated cultivars. Similar results were reported by Abd El-Lattief (2012), Daneshmand *et al*. (2012) and Piccinin *et al*. (2013). Higher yield attributes with 50% RDF + 25% RDN-VC + bio-fertilizer are thus responsible for increased yields which could also be explained by positive correlation between yield attributes and yield of wheat (Fig. 1).

Nutrient content and uptake

The content and uptake of N, P and K in grain and straw of wheat remained similar under DSBR–wheat–fallow and DSBR–wheat–mungbean cropping systems. However, numerically higher values of N, P and K uptakes in grain and straw as well as their total uptake were registered under the DSBR–wheat–mungbean cropping system. Among the nutrient sources, application of 50% RDF + 25% RDN-VC + bio-fertilizer registered significantly highest concentrations and uptake of N, P and K in both grain and straw of wheat and found on a par with 50% RDF + 25% RDN-LC + bio-fertilizer and 100% RDF (Table 2). Total uptake of N, P and K was found 59.2%,

Table 2. Effect of cropping systems and nutrient sources on nitrogen (N), phosphorus (P) and potassium (K) uptake by grain and straw and their total uptake by wheat (pooled data of 2 years)

Treatment	N uptake by grain (kg/ha)	N uptake by straw (kg/ha)	Total N uptake (kg/ha)	P uptake by grain (kg/ha)	P uptake by straw (kg/ha)	Total P uptake (kg/ha)	K uptake by grain (kg/ha)	K uptake by straw (kg/ha)	Total K uptake (kg/ha)
Cropping systems									
DSBR–wheat	67.9	27.6	95.4	14.8	3.3	18.0	18.3	94.7	112.9
DSBR–wheat–mungbean	70.9	29.4	100.3	15.6	3.5	19.0	19.3	99.25	118.6
SEm±	2.16	0.66	2.08	0.58	0.13	0.66	0.62	3.975	4.32
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient sources									
Control	51.5	18.2	69.7	11.2	2.6	13.7	14.3	72.4	86.7
100% RDF	73.8	31.4	105.2	16.0	3.6	19.6	19.6	103.2	122.9
50% RDF + 25% RDN-LC + bio.	74.5	31.2	105.6	16.4	3.6	20.0	20.1	104.0	124.1
50% RDF + 25% RDN-VC + bio.	77.7	33.2	110.9	17.1	3.8	20.9	21.2	108.3	129.5
SEm±	1.68	0.86	2.19	0.33	0.06	0.38	0.53	2.235	2.52
CD (P=0.05)	5.8	2.97	7.57	1.15	0.22	1.31	1.82	7.725	8.73

DSBR, Direct-seeded basmati rice; RDF, recommended dose of fertilizers; RDN, recommended dose of nitrogen; LC, leaf compost; VC, vermicompost; Bio, bio-fertilizers; RDF (kg/ha)=120 N : 60 P : 60 K for wheat; RDF (kg/ha)=15 N : 30 P for mungbean

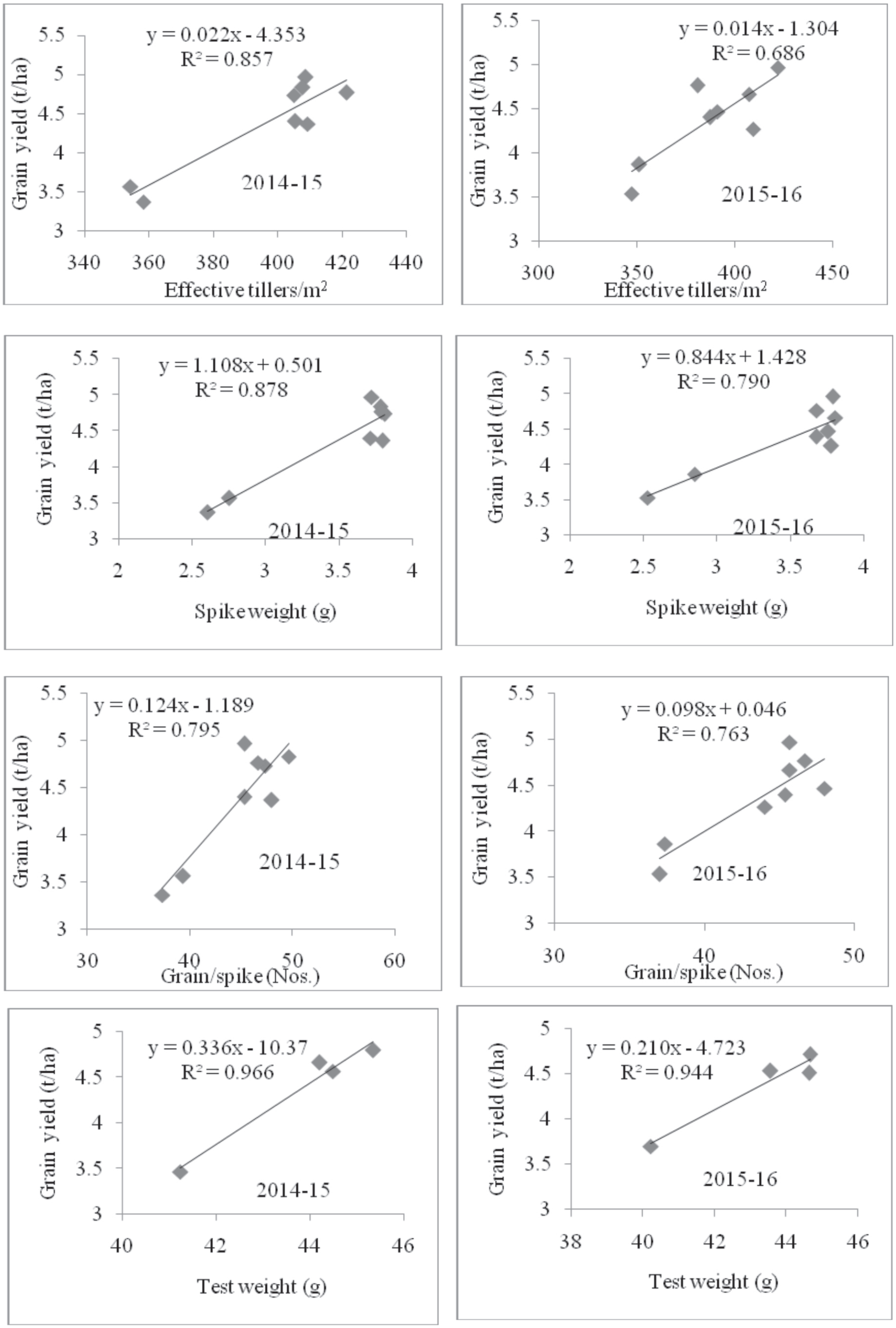

Fig. 1. Correlation of wheat grain yield with yield attributes.

52.5% and 49.3% higher with application of 50% RDF + 25% RDN-VC + bio-fertilizer in comparison to the control respectively. Similarly, with the application of 50% RDF + 25% RDN-LC + bio-fertilizer, the total uptake of N, P and K was increase to the tune of 51%, 46% and 43.1% over the control, respectively. This might be because of improved nutritional environment in the rhizosphere as well as in the plant system, leading to enhanced translocation of N, P and K in plant parts. Further, it might be the synergetic effect of vermicompost and bio-fertilizers on nutrient availability and soil health for root development and absorption of nutrients. The contribution of organic manure and inorganic improves soil physical properties, which impart better environment for root growth, thereby creates more absorptive surface for uptake of nutrients. The uptake is a function of dry-matter production and nutrient concentration. Thus, increase in concentration and dry matter increase the uptake of the nutrients. Meena *et al.* (2013) and Garai *et al.* (2014) also improved nutrient uptake by the application of organic manure.

Economics

There was non-significant variation in gross and net returns and benefit: cost ratio of wheat production between the cropping systems (Table 1). However, numerically higher values of gross returns, net returns and benefit: cost ratio were registered under DSBR–wheat mungbean than the DSBR–wheat–fallow cropping systems. Economics of wheat production was influenced significantly by diverse nutrient sources as compared to no-nutrient addition. Cost of cultivation was the highest with the application of 50% RDF + 25% RDN-LC + bio-fertilizer. The higher cost of cultivation under integrated nutrient management was due to the more cost and quantity of organic manures involved in supplying nutrients to the crop that ultimately resulted in higher cost of cultivation. Though the highest gross returns (105.07×10^3 ₹/ha) and net returns (70.65×10^3 ₹/ha) were obtained with the application of 50% RDF + 25% RDN-VC + bio-fertilizer and 100% RDF, respectively. Benefit: cost ratio was the highest in the control (2.44). Higher gross returns and net returns under 50% RDF + 25% RDN-VC or LC + bio-fertilizer could be because of better crop growth which resulted in higher yield attributes, grain and straw yields.

Thus inclusion of mungbean in cropping system enhance the system productivity as well as maintain the soil fertility. Use of organic sources of nutrients along with inorganic chemical fertilizer in conjunction with bio-fertilizer create better growing environment to the crop for its higher productivity and profitability. Better yield attributes, yield and gross returns were registered with the application of 50% RDF + 25% RDN-VC + bio-fertilizer followed by 50% RDF + 25% RDN-LC + bio-fertilizer. Based on the 2 years study therefore it is suggested that to gain higher productivity and profitability to meet requirement of ever-increasing population, crop should be supplied with diverse sources of organic and synthetic nutrients.

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