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Research Paper

Influence of integrated nutrient management on productivity, nutrient uptake and economics of maize (*Zea mays*)–yellow sarson (*Brassica rapa*) cropping system under rainfed mid hill condition

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ABSTRACT

A field experiment was conducted during 2010–12 at Kalingpong, West Bengal, to study effect of doses of chemical fertilizers along with organic sources of nutrients on growth, yield and economics of maize (*Zea mays* L.)–yellow sarson [*Brassica rapa* (L.) Var. Yellow sarson] cropping system under mid hill condition. Maximum grain and stover yields of maize were obtained with of 150% recommended dose of fertilizers (RDF) (maize) + 25% RDF (yellow sarson) (5.1 and 9.3 t/ha respectively) and was statistically at par with the application of 100% RDF (maize) + 50% RDF (yellow sarson) (5.0 and 9.3 t/ha respectively). Amongst the organic sources of nutrients, more grain and stover yields were recorded with application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha and were at par with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha, and was significantly superior to rest of the treatments. Seed yield of yellow sarson was not influenced by chemical fertilizers. Significant result was registered with stover yield, and maximum was recorded with 150% RDF (maize) + 25% RDF (yellow sarson) (3.2 t/ha), and was at par with 50% RDF (maize) + 100% RDF (yellow sarson) (3.0 t/ha). Amongst the organic sources, more seed and stover yields were recorded with application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha (1.9 t/ha). Nutrient uptake pattern was also influenced by various sources under maize–yellow sarson cropping system. The productivity of cropping system was positively influenced by various inorganic and organic treatments. Maximum maize-equivalent yield (MEY) was recorded with 50% RDF (maize) + 100% RDF (yellow sarson) (5.3 t/ha), and was at par with the 100% RDF (maize) + 50% RDF (yellow sarson) and 150% RDF (maize) + 25% RDF (yellow sarson). The highest MEY of 5.1 t/ha was recorded with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha, being at par with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha and vermicompost @ 5 t/ha, gave significantly higher value than rest of the treatments under the cropping system. Maximum net returns (₹19.4 × 10^3/ha) and benefit: cost ratio (2.1) amongst the chemical treatment, was observed with 100 % RDF (maize) + 50% RDF (yellow sarson). Application of organic nutrient sources revealed that maximum net returns (₹17.6 × 10^3/ha) and benefit: cost ratio (2.4) was registered with the FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha.

Key words : Crop production, Economic return, Maize, Nutrient uptake, Soil fertility, Yellow sarson

Yellow sarson is a potential winter (*rabi*) season crop in the north-east, especially in sub-tropical hill ecosystem of Darjeeling –Sikkim Himalayan range of India, owing to ability to exploit residual moisture. Maize–yellow sarson is the predominant cropping sequence of the region. This system is followed in the mid-hill areas without proper nutrient management leading to low productivity. Further, as the mineral fertilizers alone cannot meet the requirement of crops in cropping systems. Well-decomposed forest litter is generally used for crop production in Darjeeling hill. Forest litter is an energy source of heterotrophic organisms and all imperative link between the autotrophs and heterotrophs reduces bulk density, increase water-holding and cation-exchange capacity of soil and serves as reserve store of plant nutrients (Neelam *et al.,* 2009). Vermicompost is rich source of nutrients, humus-forming microbes and nitrogen fixers (Kale *et al*., 2008). Continuous use of organics helps build up soil humus and beneficial microbes, and improves soil physical properties. Use of organics alone does not result in spectacular increase in crop yields, due to their low nutrient status and their slow availability. Chemical fertilizers provide one or more essential plant nutrients which are readily available

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and which the soil cannot supply in adequate quantities. Judicious combination of organics and chemical fertilizers helps sustain soil productivity (Rao *et al*., 2002). In Darjeeling Himalaya, where farmers since long back are using forest litter along with FYM and vermicompost for their cropping sequence, there is need to optimize the doses of this organic fertilizers to maximize crop productivity (Subba, 2009). The present investigation was undertaken to study the effect of integrated nutrient management (INM) on growth, productivity, nutrient uptake and economics of maize–yellow sarson cropping system in mid-hills of Darjeeling-Sikkim Himalaya range.

MATERIALS AND METHODS

The field experiment was conducted at upland farm, Uttar Banga Krishi Viswavidayalay, Kalimpong (1280 m asl) under rainfed conditions during 2010–12. The soil was sandy loam, having 1.08 g/cm^3 bulk density, 2.34 g/cm^3 particle density, 63% total porosity and 42.3% maximum water-holding capacity. The soil was low in available N (210.4 kg/ha), P (10.1 kg/ha) and medium in available K (278.3 kg/ha), acidic (pH 5.3) and high in organic carbon content (1.13%). The annual average rainfall receives was 1,360 mm rainy season during the maize and 412 mm winter yellow, sarson-growing season. The experiment was conducted with split plot design replicated thrice, with 33 treatments. Three dose of inorganic nutrients which includes 50% recommended dose of fertilizer (RDF) to maize + 100% RDF to yellow sarson, 100% RDF to maize + 50% RDF to yellow sarson and 150% RDF to maize + 25% to yellow sarson comprised the main plot treatments and 11 organic sources, viz. control, FYM @ 10 t/ha, vermicompost @ 5 t/ha, forest litter @ 10 t/ha, FYM @ 5 t/ha, vermicompost @ 2.5 t/ha, forest litter @ 5 t/ha, FYM @ 5 t/ha + vermicompost @ 2.5 t/ha, FYM @ 5 t/ha + forest litter @ 5 t/ha, vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha and FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha as sub-plot treatments. The recommended dose of 120 kg N + 26.4 kg P + 33.3 kg K/ha and 50 kg N + 22.6 kg P + 16.6 kg K/ha for maize and yellow sarson, respectively were supplied through urea, single superphosphate and muriate of potash. Maize (cv. 'RCM 1-1') was sown on 9 May 2010 and 10 May 2011, whereas yellow sarson (cv. 'B 9') was sown on 2 October 2010 and 3 October 2011. Organic sources of nutrients, viz. FYM, verimocompost, well-decomposed forest litter, were applied 2 weeks before sowing of maize crop during both the years. The NPK content in FYM (0.83, 0.25, 0.91%), vermicompost (1.95, 1.89, 1.01) and forest litter (1.4, 1.8, 0.9) were determined on dry-weight basis before their application. Half of nitrogen and full dose of phosphorus and potassium were applied basal and rest of the nitrogen was applied in two equal splits at knee height and tassel-initiation stage of maize. The fertilizers were applied to yellow sarson at the time of sowing as per the treatments. System productivity in terms of maize-equivalent yield (MEY), gross return, net return and benefit: cost ratio (BCR) were calculated. Maize-equivalent yield was obtained by dividing the economic value of the produce (yield of produce × price of produce) with the price of the maize. Plant samples were analysed for uptake of nitrogen, phosphorus and potassium and post-harvest soil samples collected from 0–30 cm depth for analysing available N, P, K status and organic carbon content using standard laboratory procedure (Jackson, 1973).

RESULTS AND DISCUSSION

Growth and yield attributes of maize

Significant differences were noticed among doses of inorganic nutrients for growths and yield-attributing characters of maize except cob length (Table 1). Highest plant height, basal girth followed by number of cobs/m^2, grains/cob were obtained with application of 150% RDF (maize) + 25% RDF (yellow sarson). Grain weight/cob (91.4 g) and 100-grain weight (290.1 g) were recorded with 150% RDF to maize + 25% RDF to yellow sarson, and such increases were significant over application of 50% RDF to maize + 100% RDF to yellow sarson and 100% RDF to maize and 50% RDF to yellow sarson except for basal girth and grain weight/cob. Application of 100% RDF to maize + 50% RDF to yellow sarson also resulted in significantly higher plant height, basal girth, grains/cob, grain weight/cob and 1,000-grain weight over application of 50% RDF to maize + 100% RDF to yellow sarson.

Different sources of organics also showed significant variation in all the growth and yield-attributing characters (Table 1). Application of farmyard manure (FYM) @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha resulted in tallest plants, highest basal girth, cobs/m^2 and grain test weight, whereas application of vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha cob length, grains/cob and grain weight/cob and these 2 treatments were at par with each other for all the above parameters except grain test weight (Table 1),

Highest basal girth (7.3 cm) of maize recorded with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha was at par with all doses of organic manure applied along with vermicompost or single application of vermicompost at both the doses (Chandrasekhar *et al*., 2000). Maximum cob/m^2 registered with the FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha (7.4) was identical with FYM @ 5 t/ha + forest litter @ 5 t/ha, FYM@ 5 t/ha and vermicompost @ 5 t/ha. The highest cob length registered with vermicompost@ 2.5 t/ha +

forest litter @ 5 t/ha (16.9) was significantly higher than FYM @ 5 t/ha, FYM @ 5 t/ha + vermicompost @ 2.5 t/ha and control. The effect of organic sources on all the growth and yield-attributing characters of maize was significant over the control. Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha increased the plant height, basal girth, cob/m^2, grains/cob and grain weight/cob by 34.7, 15.5, 43.1, 16.6, 26.2% respectively, over the control. This improvement in growth and yield components of maize with application of organic manures might be because of higher availability of macro- and micronutrients with the addition of FYM, vermicompost and forest litter. Our results confirm the findings of Ahmed and Thakur (1998). Chandrasekhar *et al.* (2000) and Sujatha *et al.* (2008) observed similar beneficial effect of organic manures on different growth and yield-attributes.

Yield of maize

Grain yield is the manifestation of yield-attributing characters. Significant increase in yield of maize can be ascribed to the significant increase in the yield components with cob length exerting greater influence on the grain yield. Maximum grain and stover yields of maize were obtained with 150% RDF (maize) + 25% RDF (yellow sarson) and was statistically at par with the application of 100% RDF (maize) + 50% RDF (yellow sarson). Higher biomass production with increasing levels of fertilizers to maize could be ascribed to enhanced availability over lower doses of nutrients. This finding confirms the observation of Mahala *et al.* (2006). Harvest index was not influenced by different doses of fertilizers (Table 1).

Amongst the organic sources of nutrients, more grain and stover yields were recorded with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha, being at par with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha were significantly superior to rest of the organic sources of nutrients. Increase in maize grain and stover yields owing to vermicompost, forest litter and FYM incorporation might be attributed to steady release of nutrients to soil for longer duration after decomposition resulting in better plant growth and yield attributing characters. Munda and Islam (2007) reported similar effects of organic manure incorporation in maize. Incorporation of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha and vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha registered 59.3 and 56.4%, respectively more grain yield over the control.

Table 1. Effect of integrated nutrient-management treatment on growth and yield-attributing parameters of maize under maize–yellow sarson cropping system (pooled data of 2 years)

Treatment	Plant height (cm)	Basal girth (cm)	Cobs/m^2 (no.)	Cob length (cm)	Grains/ cob (no.)	Grain weight/ cob (g)	1,000-grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Main-plot (Inorganic nutrient)										
50% RDF (maize) + 100% RDF (yellow sarson)	193.6	5.9	5.8	14.8	301.1	60.1	265.1	3.7	6.9	35.6
100% RDF (maize) + 50% RDF (yellow sarson)	201.2	6.8	6.2	15.9	319.9	89.6	283.0	5.0	9.3	35.7
150% RDF (maize) + 25% RDF (yellow sarson)	221.9	7.1	7.4	16.7	345.1	91.4	290.3	5.1	9.3	34.3
SEm±	1.9	0.1	0.1	0.6	4.0	0.9	2.3	0.1	0.2	2.6
CD (P=0.05)	6.3	0.4	0.5	NS	11.8	2.9	6.0	0.4	0.6	NS*
Sub-plot (Organic source)										
Control	161.1	6.3	5.1	13.6	211.1	76.9	231.9	2.9	4.0	25.2
FYM @ 10 t/ha	191.3	6.8	6.8	15.7	316.1	74.1	239.8	3.1	7.5	29.3
Vermicompost @ 5 t/ha	203.4	7.4	7.1	16.1	304.1	73.1	271.6	4.0	8.3	32.4
Forest litter @10 t/ha	193.2	6.9	6.9	15.8	259.1	50.1	246.1	3.9	7.8	33.3
FYM @ 5 t/ha	186.3	6.8	7.2	14.3	300.6	71.0	234.1	3.0	5.9	27.1
Vermicompost @ 2.5 t/ha	189.6	7.0	6.9	15.6	277.2	65.1	242.9	3.5	7.4	32.1
Forest litter @ 5 t/ha	194.2	6.9	6.7	15.5	261.1	58.1	241.3	3.4	7.3	31.2
FYM @ 5 t/ha +vermicompst @ 2.5 t/ha	195.2	7.1	6.3	14.1	231.3	72.1	249.8	4.1	8.1	33.1
FYM @ 5 t/ha + forest litter @ 5 t/ha	201.8	7.0	7.1	15.9	317.9	82.1	259.1	3.2	7.2	31.1
Vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha	211.3	7.2	7.3	16.8	341.6	93.8	252.1	4.6	9.0	34.9
FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha	216.9	7.3	7.4	16.6	331.1	89.6	274.2	4.7	8.9	34.3
SEm±	2.9	0.2	0.1	0.8	5.0	0.7	2.3	0.1	0.1	0.9
CD (P=0.05)	9.3	0.6	0.5	2.4	14.9	2.1	7.1	0.3	0.4	2.3

NS, Non-significant

Growth and yield attributes of yellow sarson

The application of organics and or inorganic fertilizers applied to maize and direct application of fertilizers to yellow sarson significantly increased all the growth and yield-attributing characters of yellow sarson over the control.

Application of 50% RDF (maize) + 100% RDF (yellow sarson) resulted in statistically similar plant height, siliquae/plant, seeds/siliqua and 1,000-seed weight with that of 150% RDF (maize) + 25% RDF (yellow sarson) (Table 2). Branches/plant with 50% RDF (maize) + 100% RDF (yellow sarson) were significantly higher than the other doses. Seeds/siliqua and 1,000-seed weight was registered with 150% RDF (maize) + 25% RDF (yellow sarson).

Various organic sources of nutrients showed significant differences in all the growth and yield-attributing characters of yellow sarson (Table 2). Highest plant height observed with application of FYM @ 5 t/ha + forest litter @ 5 t/ha was at par with application of FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha (65.9 cm) and vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha (63.1), and superior to all the other treatments. Maximum branches/plant registered with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha (7.0), resulted in significantly higher number of branches/plant over the control, FYM @ 10 t/ha, vermicompost @ 5 t/ha and forest litter @ 10 t/ha but similar number of siliquae/plant and seed/siliqua to that of vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha. Number of seeds/siliqua with these treatments was also similar to that obtained with forest litter @ 10 t/ha, vermicompost @ 5 t/ha and FYM @10 t/ha. Significantly lower number of siliquae/plant obtained with FYM @ 5 t/ha was at par with FYM @ 5 t/ha + vermicompst @ 2.5 t/ha and control. Highest 1,000-seed weight obtained with application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha was at par with vermicompost @ 5 t/ha only. Kumar *et al.* (2005) reported similar beneficial effect of organic manures in maize–wheat cropping system.

Yield of yellow sarson

Application of nutrients through inorganic fertilizers did not influence seed yield of yellow sarson (Table 2). However, application of 150% RDF (maize) + 25% RDF (yellow sarson) (1.3 t/ha) resulted in only marginal increase in seed yield over other doses. Stover yield obtained with 150% RDF (maize) + 25% RDF (yellow sarson) (3.2 t/ha) was at par with 50% RDF (maize) + 100% RDF (yellow sarson) (3.0 t/ha). Chanda (2007) reported similar

Table 2. Effect of nutrient management on growth and yield-attributing parameters of yellow-sarson under maize–yellow sarson cropping system (pooled data of 2 years)

Treatment	Plant height (cm)	Branches/ plant (no.)	Siliquae/ plant (no.)	Seeds/ siliquae (no.)	1,000-seed weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
Main-plot (Inorganic nutrient)								
50% RDF (maize) + 100% RDF (yellow sarson)	60.2	7.2	101.3	10.5	4.1	1.4	3.0	27.3
100% RDF (maize) + 50% RDF (yellow sarson)	56.1	5.7	81.3	9.9	3.7	1.3	2.5	30.2
150% RDF (maize) + 25% RDF (yellow sarson)	63.1	6.0	98.0	10.2	4.2	1.2	3.2	30.6
SEm±	1.3	0.1	2.9	0.2	0.2	0.1	0.1	2.4
CD (P=0.05)	4.1	0.4	9.7	0.9	NS*	NS	0.4	NS
Sub-plot (Organic source)								
Control	50.4	4.3	57.8	7.8	3.8	0.5	1.2	25.2
FYM @10 t/ha	58.1	5.1	81.3	9.8	3.9	1.0	2.1	32.6
Vermicompost @ 5 t/ha	59.4	5.9	86.1	10.3	4.7	1.3	3.1	30.9
Forest litter @ 10 t/ha	55.8	5.1	80.1	10.2	4.1	1.1	3.4	25.1
FYM @ 5 t/ha	50.2	6.0	60.1	7.0	4.2	0.8	2.1	28.6
Vermicompost @ 2.5 t/ha	56.1	6.4	79.4	9.1	3.8	0.9	2.7	25.5
Forest litter @ 5 t/ha	56.3	6.3	76.1	8.9	4.1	0.6	1.5	34.2
FYM @ 5 t/ha + vermicompst @ 2.5 t/ha	51.6	6.2	73.2	7.0	4.2	0.6	1.9	26.9
FYM @ 5 t/ha + forest litter @ 5 t/ha	67.4	6.9	90.1	8.9	4.1	1.4	3.0	32.1
Vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha	63.1	6.0	94.3	11.0	4.3	1.8	3.9	31.8
FYM @2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha	65.9	7.0	98.6	10.7	4.7	1.9	4.0	32.1
SEm±	1.9	0.3	2.8	0.6	0.1	0.2	0.2	4.3
CD (P=0.05)	5.6	1.0	8.1	1.6	0.2	0.7	0.8	NS

NS, Non-significant

observation. Beneficial effect of inorganic fertilizers applied to preceding crop on the productivity of succeeding crop was also observed by Das *et al.* (2004). Harvest index of yellow sarson was not influenced by doses of inorganic fertilizers. Incorporation of forest litter @10 t/ha (34.2) resulted in the highest harvest index with respect to rest of the organic combination.

Amongst the organic sources, more seed and stover yield was recorded with FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha (1.9 t/ha) over other treatments. Seed yield with this treatment was at par with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha (1.8 t/ha), FYM @ 5 t/ha + forest litter @ 5 t/ha (1.4 t/ha) and vermicompost @ 5 t/ha (1.3 t/ha). Similarly, stover yield with this treatment was at par with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha (3.9 t/ha) and forest litter @10 t/ha (3.4 t/ha). Singh and Sureja (2008) also reported increase in seed yield of mustard with incorporation of forest litter. Application of FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha, vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha, FYM @ 5 t/ha + forest litter @ 5 t/ha and vermicompost @ 5 t/ha resulted in 72.3, 70.1, 62.9, 61.5 %, respectively, more seed yield over the control.

Nutrient uptake pattern of maize

Amongst various treatments uptake of primary nutrient significantly varied with response to different treatments combinations. Maximum uptake of nitrogen, phosphorus and potassium registered with the application of 150% RDF (maize) + 25% RDF (yellow sarson) showed parity with the application of 100% RDF (maize) + 50% RDF (yellow sarson). However, least uptake was recorded with low dose of RDF applied to maize crop. Higher nutrient availability in soil might have contributed to higher grain and stover yield of maize (Table 3). Singh and Brar (2007) also observed higher total nitrogen and build up of phosphorus in the soil with the increase in levels of nitrogen and phosphorus application in maize–wheat rotation.

Application of vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha, FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha, FYM @ 5 t/ha + vermicompst @ 2.5 t/ha, forest litter @ 10 t/ha and vermicompost @ 5 t/ha resulted in similar nitrogen uptake (Table 3). During vermicomposting, the C : N ratio was narrowed down substantially over normal compost. The lower C : N ratio ensures immediate release of nitrogen from soil to plant (Bansal and Kapoor, 2000). Uptake of phosphorus was more with the application of vermicompost @ 2.5 t/ha +

Table 3. Nutrient uptake and soil fertility at final harvest (kg/ha) as influenced by integrated nutrient management practices (pooled data of 2 years)

Treatment	Total nutrient uptake (kg/ha)						Soil fertility after harvesting (kg/ha)			Organic carbon
	Maize			Yellow sarson						
	N	P	K	N	P	K	N	P	K	(%)
Main-plot (Inorganic nutrient)										
50% RDF (maize) + 100% RDF (yellow sarson)	59.9	15.3	43.2	45.2	14.9	39.5	236.1	15.6	258.2	1.4
100% RDF (maize) + 50% RDF (yellow sarson)	98.6	18.5	85.2	27.6	10.9	22.3	181.4	14.3	246.2	1.2
150% RDF (maize) + 25% RDF (yellow sarson)	100.3	21.3	90.4	49.3	14.8	36.2	211.3	15.9	252.2	1.4
SEm±	2.8	1.2	3.8	4.2	0.9	1.2	3.3	0.9	2.2	0.1
CD (P=0.05)	8.9	3.6	11.8	13.1	2.1	3.6	9.9	NS	6.8	0.2
Sub-lot (Organic source)										
Control	55.1	10.0	64.9	20.0	9.9	19.1	142.1	9.0	142.8	0.8
FYM @ 10 t/ha	77.8	21.0	71.4	34.1	11.0	21.8	202.3	10.2	241.3	1.4
Vermicompost @ 5 t/ha	93.1	23.0	85.3	45.6	16.9	23.6	214.2	15.0	251.4	1.4
Forest litter @ 10 t/ha	86.2	17.5	75.4	47.8	15.9	26.2	202.3	17.6	250.1	1.7
FYM @ 5 t/ha	60.4	16.0	61.2	33.3	10.3	26.1	172.0	15.2	171.3	1.3
Vermicompost @ 2.5 t/ha	83.2	16.3	70.1	35.2	11.9	26.2	196.2	10.2	201.0	1.2
Forest litter @ 5 t/ha	70.1	20.1	68.2	28.1	9.1	30.2	193.1	13.6	195.3	1.6
FYM @5 t/ha + vermicompst @ 2.5 t/ha	89.6	18.4	78.3	30.9	10.0	25.1	189.0	12.7	184.0	1.3
FYM @ 5 t/ha + forest litter @ 5 t/ha	65.2	18.1	67.3	36.5	12.3	40.1	219.3	12.3	256.2	1.5
Vermicompost@ 2.5 t/ha + forest litter @ 5 t/ha	101.1	26.3	86.3	46.2	15.2	34.9	215.3	15.2	259.2	1.6
FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha	94.9	24.9	88.9	51.3	18.7	36.5	218.3	14.0	255.6	1.4
SEm±	3.9	0.9	1.9	2.6	0.2	1.2	5.4	1.2	4.1	0.1
CD (P=0.05)	11.6	2.9	5.9	6.1	0.8	4.0	15.0	3.4	12.3	0.2

forest litter @ 5 t/ha and was at par with the FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha (Table 3). Forest litter plays a fundamental role in the nutrient turnover and mobilized fixed phosphorus in acidic soil and enhances phosphorus uptake by crop (Bienkowski *et al*., 2006). Potassium uptake was the highest with the FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha and was at par with the vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha and vermicompost @ 5 t/ha. However, significantly low nutrient uptake was registered with the control and was closely followed by FYM @ 5 t/ha.

Nutrient uptake pattern of yellow sarson

Application of 150% RDF (maize) + 25% RDF (yellow sarson) resulted in highest N uptake, whereas 50% RDF (maize) + 100% RDF (yellow sarson) resulted in highest P and K uptake and both treatments were at par with each other (Table 3).

Application of FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha resulted in the highest uptake of nitrogen and phosphorus and such an increase in nitrogen uptake was at par with incorporation of vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha. The highest potassium uptake recorded with application of FYM@ 5 t/ha + forest litter @ 5 t/ha was similar to that obtained with FYM @ 2.5 t/ha + vermicompost @1.25 t/ha + forest litter @ 2.5 t/ha and significantly higher than the other treatments of organic manure. More nutrient uptake by this treatment might be increased nutrient availability, influences rhizosphere bacteria and microorganisms to increase mineral nutrition of plants by changing root-uptake characteristics, modification of root morphology or alteration of uptake mechanism, relative growth rate or internal composition of mustard plant (Habbasha and Taha, 2011). Ramesh *et al.* (2009) also reported increased in nutrient uptake by mustard crop with application of organic sources of fertilizers.

Soil fertility status after harvesting

At harvest significantly highest available N and K in soil were observed with 50% RDF to maize and 100% applied to yellow sarson compared to the other treatments of inorganic fertilizers treatments (Table 3). However, available phosphorus was not influenced by different treatments. Application of 50% RDF (maize) + 100% RDF (yellow sarson) also resulted the higher but similar soil organic carbon with that of 150% RDF (maize) + 25% RDF (yellow sarson).

Amongst various organic manures, application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha registered the maximum available nitrogen in soil and showed parity with the FYM @ 5 t/ha + forest litter @ 5 t/ha, vermicompost @ 5 t/ha, forest litter @ 10 t/ha and FYM @ 10 t/ha. Available phosphorus was more with application of forest litter @ 10 t/ha and was at par only with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha (Table 3). However, highest potassium availability was observed with vermicompost @ 2.5 t/ha + forest litter @

Table 4. Effect of integrated nutrient management on productivity and economics of maize–mustard cropping system (pooled data of 2 years)

Treatment	Maize equivalent yield (t/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Main-plot (Inorganic sources)				
50% RDF (maize) + 100% RDF (yellow sarson)	5.3	30.5	14.1	1.8
100% RDF (Maize) + 50% RDF (yellow sarson)	5.0	37.0	19.4	2.1
150% RDF (Maize) + 25% RDF (yellow sarson)	5.1	38.2	16.3	1.7
SEm±	0.1			
CD (P=0.05)	0.3			
Sub-plot (Organic source)				
Control	2.9	11.1	2.3	1.2
FYM @ 10 t/ha	3.7	28.3	12.9	1.8
Vermicompost @ 5 t/ha	4.7	31.4	14.8	1.9
Forest litter @ 10 t/ha	3.7	29.8	13.2	1.8
FYM @ 5 t/ha	3.0	17.4	8.4	1.9
Vermicompost @ 2.5 t/ha	4.3	22.2	11.0	1.9
Forest litter @ 5 t/ha	4.0	20.3	10.4	2.0
FYM @ 5 t/ha + vermicompst @ 2.5 t/ha	4.1	20.5	9.1	1.7
FYM @ 5 t/ha + forest litter @ 5 t/ha	4.1	26.7	15.7	2.4
Vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha	4.7	29.3	16.7	2.3
FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha	5.1	29.4	17.6	2.4
SEm±	0.1			
CD (P=0.05)	0.3			

5 t/ha and was found at par with the FYM @ 5 t/ha + forest litter @ 5 t/ha, FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha, vermicompost @ 5 t/ha and forest litter @ 10 t/ha. Lowest values of these primary nutrients were registered with the control and were closely followed by FYM @ 5 t/ha.

Organic carbon

Subplot treatment showed maximum organic carbon (%) with the application of forest litter @ 10 t/ha and was at par with the vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha (Table 3). Nether (1999) also reported improvement in inorganic carbon content with the incorporation of vermicompost along with other organic sources.

System productivity and economics

The productivity of maize–yellow sarson cropping system was positively influenced by different inorganic and organic treatments (Table 4). Maximum maize-equivalent yield (MEY) was recorded with 50% RDF (maize) + 100% RDF (yellow sarson) and was at par with the 100% RDF (maize) + 50% RDF (yellow sarson) and 150% RDF (maize) + 25% RDF (yellow sarson). The MEY of maize–yellow sarson cropping sequence also varied significantly with different organic nutrient treatments (Table 4). Highest MEY was recorded with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha, which was at par with vermicompost @ 2.5 t/ha + forest litter @ 5 t/ha and vermicompost @ 5 t/ha, and significantly higher than rest of the treatments. The maize-equivalent yield with FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha was increased by 54.2% over the control. The maximum net returns and benefit: cost ratio were observed with application of 100% RDF (maize) + 50% RDF (yellow sarson). This treatment gave higher productivity, which ultimately produced more net monetary return. This result confirm with the findings of Munda and Islam (2007). Application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha showed the maximum net returns and benefit: cost ratio. The highest net return as well as benefit: cost ratio was registered with application of various organic sources of nutrient in combinations instead of their application alone. Our results confirm the findings of Tomar and Tiwari (1990). Improvement in soil health owing to continuous application of organic manure provides higher return.

It was concluded that 100% RDF to maize and 50% RDF to yellow sarson along with application of FYM @ 2.5 t/ha + vermicompost @ 1.25 t/ha + forest litter @ 2.5 t/ha to maize alone was sufficient in maize–yellow sarson cropping system under rainfed mid hill condition.

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