

Response of safflower (*Carthamus tinctorius*) to *in-situ* green manuring and nitrogen: phosphorus levels under rainfed condition

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2011–12 and 2012–13 at Agricultural Research Station, Annigeri (Northern Dry Zone of Karnataka-Zone-3), Dharwad, Karnataka, response of safflower (*Carthamus tinctorius* L.) to *in-situ* green manuring and NP levels under rainfed condition. The experiment consisted of 4 green-manure crops, viz. sunhemp (*Crotalaria juncea* L.), greengram [*Vigna radiata* (L.) R. Wilczek], cowpea [*Vigna unguiculata* (L.) Walp] and fallow, grown during the rainy season 4 fertility levels to succeeding safflower (0 : 0, 20 : 20, 30 : 30 and 40 : 40 N : P₂O₅ kg/ha) during the winter (*rabi*) season. The experiment was laid out in split-plot design with 3 replications. Among the green manures, incorporation cowpea and sunhemp resulted in significantly higher safflower seed yield (1.25 and 1.15 t/ha), net returns (₹22,319 and ₹19,551) and benefit: cost ratio (3.17 and 2.89), respectively, than greengram and fallow treatments. Among the fertility levels, higher fertility level (40 : 40 N : P₂O₅ kg/ha) recorded significantly higher seed yield (1.32 t/ha), net returns (₹23,833/ha) and benefit: cost ratio (3.25) than lower fertility levels. Among the interaction, significantly higher seed yield (1.57 and 1.42 t/ha), net returns (₹30,227 and ₹26,263/ha) and benefit: cost ratio (3.85 and 3.45), respectively, were recorded in cowpea and sunhemp plots coupled with higher fertility level (40 : 40 N : P₂O₅ kg/ha) than fallow-safflower system with higher fertility level.

Key words : Cowpea, Fertility level, In-situ green manures, Safflower, Seed yield, Sunhemp,

Safflower is one of the most economically important drought-tolerant edible oilseed crops of drylands owing to its deep root-system and spiny leaves. Crop is generally grown in post rainy season on moisture-retentive soils of Deccan plateau. India ranked the first in global safflower production and acreage. During 2012–13, safflower was grown in our country over an area of 3 lakh ha which accounts 41% of global safflower area, with production of 1.89 lakh tonnes representing 29% of global production. Average productivity across India is quite low (630 kg/ha) in comparison to global productivity (893 kg/ha) (The Hindu, 2011). Lower productivity calls for greater atten-

tion in increasing the productivity of the crop by increasing fertility status of soils and also by applying balanced dose of required nutrients. Increasing soil fertility by adding external inputs in dryland agriculture are hindered by their expensive cost coupled with non-availability of compost, crop residues etc. *In-situ* green manuring is one of the options to improve soil fertility. In Northern Dry Zone (Zone-3) of Karnataka, farmers leave their land fallow during the rainy (*kharif*) season and cultivate safflower during the winter (*rabi*) season under residual soil moisture. This gives an opportunity to grow green manure crops as catch crop to improve soil fertility and to enhance the productivity of succeeding crop. Green manure crops are known to produce 15–22 t of green matter/ha (AICRPDA 2003a). Therefore, in order to achieve enhanced sustained yield through improvement of soil productivity, there is a need to work out proper management techniques to grow *in-situ* green-manure crops during *kharif* and application of NP levels to the succeeding safflower in rainfed conditions. Hence present investigation was carried out to study response of safflower to *in-situ* green manuring and NP levels under rainfed condition.

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MATERIALS AND METHODS

The field study was conducted during *kharif* and *rabi* seasons of 2011–12 and 2012–13 at the Agricultural Research Station, (15° 26' 0" North, 75° 26' 0" South), University of Agricultural Sciences, Annigeri, Dharwad, Karnataka. The soil of the experimental site was deep black in texture with bulk density 1.27 g/cc, pH 7.9, organic carbon 4.9 g/kg, available N 218 kg/ha, available P₂O₅ 19 kg/ha and available K₂O 347 kg/ha. The experiment was laid out in split-plot design, comprising of 4 green manure crops, viz. sunnhemp, greengram, cowpea and fallow, grown during *kharif* and 4 fertility levels to succeeding crop of safflower (0:0, 20:20, 30:30 and 40:40 N: P₂O₅ kg/ha). Sunnhemp, cowpea and greengram green manures were line sown on 3 June 2011 in the first year and 20 July 2012 in the second year with the row spacing of 30 cm by using seed rate of 25 kg/ha. Green manures were fertilized with a common dose of fertilizer (25 : 50 : 25 kg N : P₂O₅ : K₂O kg/ha) applied by using bullock drawn mouldboard plough. The rainfall received during crop-growth period of green manures was 110 and 142 mm during 2011–12 and 2012–13. During safflower growth period 101 and 155 mm rainfall was received (2011–12 and 2012–13, respectively). Among greenmanures, cowpea and sunnhemp recorded higher phytomass (green matter) (12.49–14.04 t/ha), biomass (2.27–2.29 t/ha), N accumulation (44.24–50.43 kg/ha), P accumulation (11.08–17.90 kg/ha) and K accumulation (34.28–40.23 kg/ha) than greengram (Table 1). The nutrient status of soil was estimated after incorporation of green manures but before sowing of safflower. Available N (252.7 kg/ha) and K (371.0 kg/ha) status higher with sunnhemp followed by cowpea, while available P was higher in cowpea green-manured plot (27.2 kg/ha) than green gram.

During the *rabi* season, the safflower (cv. Annigeri-1) was sown on 21 October 2011 in the first year and 12 November 2012 in the second year at a spacing of 45 cm × 30 cm. The N and P fertilizers were applied according to treatments. The experiment plots were intercultivated twice followed by hand-weeding carried out 35 and 60

days after sowing (DAS). The intercultivation was carried out using blade harrow. The safflower was harvested 130 days after sowing. Melathian dusting was carried out at 15 DAS to control ants and leaf-eating insects. To control aphids and leaf-eating caterpillar, dinethoate and indoxacaob were sprayed when insects reach economic threshold level. Soil-enzyme activities were assayed at 60 DAS. The dehydrogenase activity was assayed by TTC (2, 3, 5-triphenyl tetrazolium chloride) method and phosphatase activity by PNP (P-Nitrophenol Phosphate) method. The experimental data were statistical analysed by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in 'F' test was given at 5%. Critical difference (CD) values were given in the tables at 5% level of significance, wherever the 'F' test was significant at 5% level.

RESULTS AND DISCUSSION

Effect of in-situ green manures and NP levels on growth attributes

In-situ green manures, NP levels and their interactions influenced the growth attributes of safflower significantly at harvest (Tables 2, 3). Among the green-manures, cowpea and sunnhemp green manured plots recorded significantly higher total dry-matter production (TDMP) than greengram. The higher TDMP in these treatments could be because of significantly higher plant height, higher leaf-area index (LAI), primary and secondary branches/plant. The similar findings were reported by Kler and Walia, (2006) and Biradar *et al.* (2012a). The TDMP of safflower increased with successive increase in the levels of N and P. Application of recommended N and P (40 : 40 kg N : P₂O₅kg/ha) to safflower resulted in significantly higher TDMP than the other NP levels. The better performance of former treatment was on account of significant improvement in plant height, higher LAI, primary and secondary branches/plant. The lowest growth attributes were recorded with no-fertilizer treatment. The results are in agreement with the findings of Vishwanath *et al.* (2006) and Christos and Christos (2009). Among the interactions, cowpea and sunnhemp green-manured plots applied with

Table 1. Phytomass, biomass, nutrient content, nutrients added by *in-situ* green manures and available nutrients before sowing of safflower (pooled data of 2 years)

Green manure crop	Phytomass (green matter) (t/ha)	Biomass (t/ha)	Nutrient content of green manures (%)			Nutrient added by green manures(kg/ha)			Available nutrient status in soil(kg/ha)		
			N	P	K	N	P	K	N	P	K
Sunnhemp	12.49	2.27	2.2	0.48	1.8	50.43	11.08	40.23	252.7	23.5	371.0
Greengram	9.92	1.76	1.4	0.53	1.2	25.62	9.46	21.64	230.9	24.2	352.3
Cowpea	14.04	2.29	1.9	0.77	1.5	44.24	17.90	34.28	247.3	27.2	364.9

Table 2. Effect of *in-situ* green manuring and nitrogen: phosphorus levels on growth attributes of succeeding safflower at harvesting (pooled data of 2 years)

Treatment	Plant height (cm)				Leaf-area index (LAI) (90 DAS)				Total dry-matter production (g/plant)					
	Main plots (green-manures)		Mean		Main plots (green-manures)		Mean		Main plots (green-manures)		Mean			
	Sunnhemp	Green gram	Cowpea	Fallow	Sunnhemp	Green gram	Cowpea	Fallow	Sunnhemp	Green gram	Cowpea	Fallow		
Subplots (N : P kg/ha)														
0 : 0	74.9	70.6	75.3	66.2	71.7	2.86	2.22	2.69	1.85	110.0	107.5	109.9	102.0	107.3
20 : 20	77.0	76.2	77.0	69.0	74.8	3.09	2.37	2.85	2.08	124.2	126.6	130.0	120.1	125.2
30 : 30	78.4	77.6	79.0	70.4	76.4	3.30	2.48	2.98	2.17	139.6	136.8	144.9	129.2	137.6
40 : 40	80.7	78.8	80.9	73.7	78.6	3.51	2.71	3.20	2.33	156.0	153.3	162.2	145.6	154.3
Mean	77.8	75.8	78.1	69.8	76.4	3.19	2.45	2.93	2.11	132.4	131.1	136.7	124.2	132.4
	SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)			
Main plot	1.22		4.22		0.062		0.215		1.85		6.42			
Subplot	0.88		2.58		0.053		0.154		1.87		5.45			
Interaction	1.77		5.15		0.106		0.308		3.73		10.90			

recommended N and P to safflower (40 : 40 kg N : P₂O₅/ha) recorded higher TDMP than the other combinations. The higher growth parameters in above treatment combinations were owing to incorporation of higher phytomass and biomass, which in turn added higher N, P and K (Table 1) and higher N uptake and P uptake by safflower (Fig. 2).

Effect of in-situ green manures and NP levels on yield attributes and yield

The seed yield and yield-attributing characters of safflower was substantially influenced by incorporation of green-manure crops and NP and levels (Tables 4, 5). The cowpea and sunnhemp green-manured plots recorded significantly higher yield attributes, viz. capsules/plant, seed weight/plant and test weight (Table 4) than greengram green-manured plot. Similar increases in yield attributes with incorporation of green manures were reported in safflower by Nooli (2001), Karle *et al.* (2007) and Biradar *et al.* (2012b). Among the nutrients levels (N:P levels), application of 40:40 kg N: P₂O₅ per ha (RDF) was recorded significantly higher yield attributes such as number of capsules per plant (25.1), seed weight/plant (19.2 g) and test weight (Table 4). Similar increases in yield attributes with graded levels of NP were reported in safflower by Naik *et al.* (2008), Golzarfar *et al.* (2011), Zareie *et al.* (2011), Biradar *et al.* (2012b) and Mohamed *et al.* (2012). The incorporation of cowpea and sunnhemp green manures along with RDF (GM₁F₄ and GM₃F₄) recorded significantly higher yield attributes such as capsules/plant, seed weight/plant and test weight (Table 4). The higher yield-attributing parameters with these treatment combinations could be owing to increased availability of nutrients as reflected in the higher soil available nutrients before sowing of safflower (Table 1). The available soil NPK with cowpea and sunnhemp green-manured plots was substantially higher than greengram and fallow plots.

Cowpea and sunnhemp green-manured plots recorded significantly higher safflower seed yield, being 24.35 and 13.52% higher compared to incorporation of green gram (1.01 t/ha) and 36.28 and 49.28% higher compared to fallow-safflower system (Table 5). The higher seed yield of safflower with cowpea and sunnhemp green-manured plots was owing to incorporation of higher phytomass and biomass which in turn added higher N, P and K (Table 1).

The sunnhemp green-manured plots recorded higher safflower seed yield mainly on account of higher N accumulation which helped luxurious growth of safflower. Cowpea although added lesser N but recorded higher safflower seed yield on account of higher P accumulation. Further, the addition of higher biomass by sunnhemp and cowpea might have also improved the water-holding ca-

Table 3. Effect of in-situ green-manuring, nitrogen: phosphorus levels on primary and secondary branches/plant of succeeding safflower at harvesting (pooled data of 2 years)

Treatment	Primary branches/plant				Mean	Secondary branches/plant				Mean
	Main plots (green-manures)					Main plots (green-manures)				
	Sunnhemp	Greengram	Cowpea	Fallow		Sunnhemp	Greengram	Cowpea	Fallow	
Subplots (N : P kg/ha)										
0 : 0	9.8	8.3	9.9	7.2	8.8	18.1	15.7	18.8	14.0	16.6
20 : 20	11.2	9.6	10.4	8.5	9.9	20.4	18.1	20.3	16.5	18.8
30 : 30	11.7	10.3	11.7	9.5	10.8	22.0	19.7	22.5	18.4	20.6
40 : 40	12.4	11.3	12.2	10.5	11.6	23.4	21.8	23.5	20.5	22.3

capacity of soil which inturn leads to improved growth and yield components. The simple correlation coefficient between growth and yield parameters with seed yield were significant (Table 6). The similar increase in seed yield of safflower due to green manuring have been reported by Nooli *et al.* (2001) and Biradar *et al.* (2012b). Application of 40 : 40 N : P₂O₅ kg/ha recorded significantly higher seed yield which was 17.91, 37.38 and 58.82% higher compared to 30 : 30, 20 : 20 and 00 : 00 kg N : P₂O₅ kg/ha, respectively. Yield improvement in RDF treatment was primarily owing to higher N supply and yield further improved in presence of P₂O₅ up to 40 kg/ha. These results are in conformity with the findings of Naik *et al.* (2008), Sui and John (2010), Zareie *et al.* (2011), Biradar *et al.* (2012b) and Mohamed *et al.* (2012).

The interaction effect of incorporation green-manures and N : P levels showed significant variations in seed yield of safflower (Table 5). The fallow plot receiving 40 : 40 N : P₂O₅ kg/ha (GM₄F₄) (RDF) recorded seed yield of 1.07 t/ha which was on par with cowpea and sunnhemp GM plots coupled with 20 : 20 N : P₂O₅ kg/ha (GM₃F₂ and

GM₁F₂, and greengram GM treatment coupled with 30 : 30 kg N : P₂O₅ kg/ha (GM₂F₃). This clearly indicates that cowpea and sunnhemp green-manures saved N and P to the tune of 50%, while greengram GM saved 25% of recommended N and P. The results are in conformity with findings of UAS (2003b). Further, seed yield of safflower could be increased to 1.57 t/ha and 1.42 t/ha by cowpea and sunnhemp green manuring, respectively applied with 40 : 40 N : P₂O₅ kg/ha. The increase in seed yield was 47.23 and 33.27% than fallow-safflower sequence applied with 100 % RDF. Similar results were earlier reported by UAS (2003b) and Biradar *et al.* (2012b). The differential response of safflower to different green manures and N : P levels could be related to their differential response in terms of growth (Table 2, 3) and yield-contributing characters (Table 4), nutrient (N and P) uptake by safflower and enzyme activity in the soil (Table 7). The higher seed yield of safflower in cowpea and sunnhemp green-manured plots were owing to higher yield attributes (capsules/plant, seed weight/plant and 1,000-seed weight) parameters (Tables 2, 3, 4). The safflower seed yield was

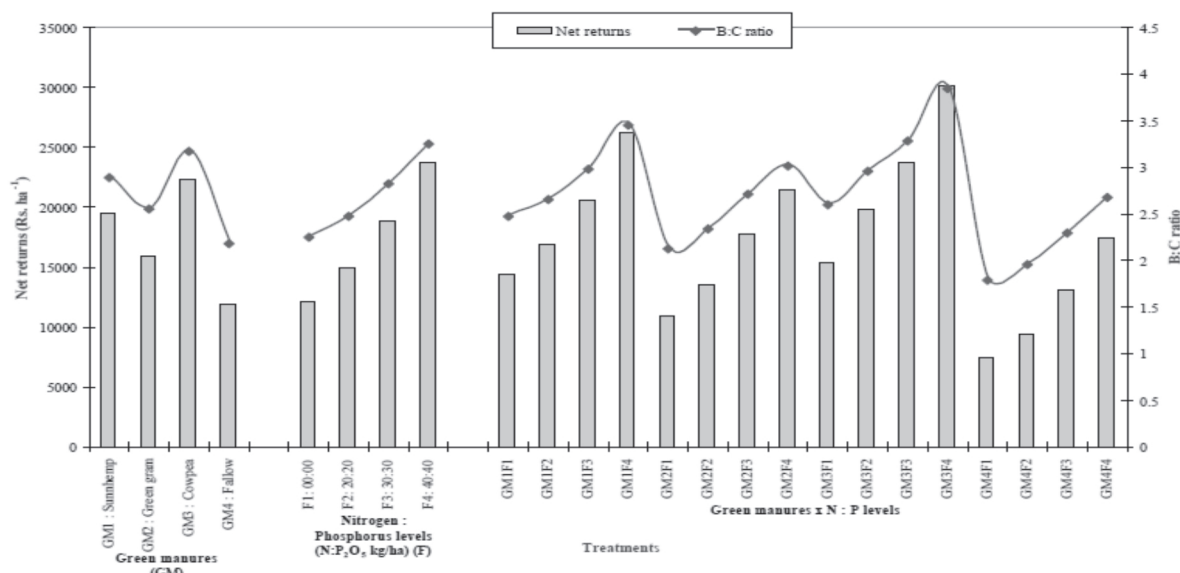


Fig. 1. Effect of in-situ green manuring and nitrogen: phosphorus levels on economics of succeeding safflower (pooled data of 2 years)

Table 4. Effect of *in-situ* green manuring and nitrogen: phosphorus levels on yield attributes of succeeding safflower (pooled data of 2 years)

Treatment	Capsules/plant				Seed weight/plant (g)				1,000-seed weight (g)			
	Main plots (green-manures)				Main plots (green-manures)				Main plots (green-manures)			
	Sunnhemp	Cowpea	Fallow	Mean	Sunnhemp	Cowpea	Fallow	Mean	Sunnhemp	Cowpea	Fallow	Mean
Subplots (N : P kg/ha)												
0 : 0	18.9	15.0	19.7	16.5	13.3	11.3	8.6	11.9	57.7	57.2	56.8	57.3
20 : 20	22.7	18.7	22.8	20.0	15.9	13.5	10.8	14.3	58.3	57.9	57.2	57.9
30 : 30	24.8	21.0	25.2	22.5	18.3	16.2	13.1	16.5	58.4	58.0	57.5	58.1
40 : 40	26.9	24.1	27.3	25.1	20.1	18.2	22.7	19.2	58.6	58.2	57.7	58.3
Mean	23.3	19.7	23.7	21.3	16.9	14.8	12.1	16.5	58.2	57.8	57.3	58.1
SEm±	CD (P=0.05)				CD (P=0.05)				CD (P=0.05)			
Main plot	0.58				0.55				0.11			
Subplot	0.19				0.46				0.14			
Interaction	0.39				0.91				0.27			

positively correlated with all the growth and yield parameters (Table 6).

Effect of in-situ leguminous green manures and N : P levels on economics

Net returns and benefit: cost ratio (B : C) ratio of safflower differed significantly due to *in-situ* green manures, NP levels and their interactions (Fig. 1). Significantly higher net returns and B:C ratio were noticed in cowpea GM. However, sunnhemp-incorporated plot remained at par with the net returns of former treatment. The lowest net returns and B : C ratio were recorded with non-green manured plot. Significantly higher net returns and B : C ratio were recorded with higher NP level when compared to all lower NP levels. The lowest net return and B : C ratio were recorded with no fertilizer treatment. Among the interactions, higher net returns and B : C ratio were obtained in cowpea GM with recommended NP (40 : 40 N : P₂O₅ kg/ha) when compared with other combinations. However, sunnhemp-incorporated plot applied with 40 : 40 kg N : P₂O₅/ha remained at par with the former treatment. Fallow plot with no-fertilizer accounted for significantly lower net returns and B : C ratio. The results confirm the findings of Dasaraddi (1998), Biradar *et al.* (2012b) and Singh and Singh (2013).

Effect of in-situ green manures and N:P levels on N and P uptake

Significantly higher N uptake was noticed in sunnhemp GM compared to greengram and fallow treatments. Incorporation of cowpea GM was however on par a with sunnhemp green-manured plot. The nitrogen uptake due to graded application of different levels of N and P was sig-

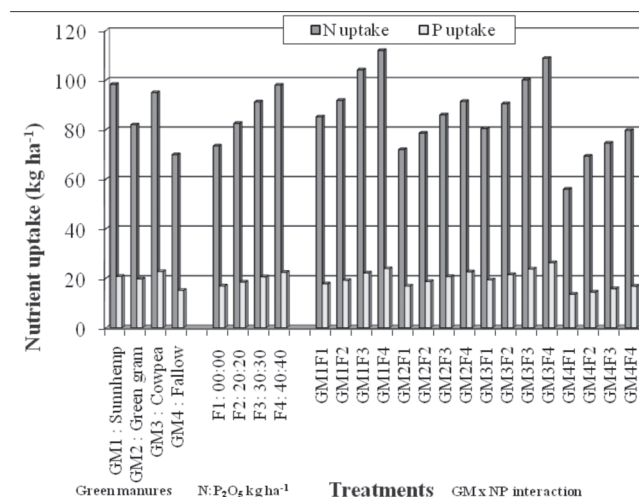


Fig. 3. Effect of in-situ green-manuring and nitrogen: phosphorus levels on nutrient uptake (N and P) by succeeding safflower (pooled data of 2 years)

Table 5. Effect of *in-situ* green manuring and nitrogen: phosphorus levels on yield of succeeding safflower (pooled data of 2 years)

Treatment	Seed yield (t/ha)				Mean
	Main plots (green-manures)				
	Sunnhemp	Greengram	Cowpea	Fallow	
0 : 0	0.93	0.79	0.96	0.65	0.83
20 : 20	1.04	0.89	1.15	0.74	0.96
30 : 30	1.20	1.08	1.31	0.89	1.12
40 : 40	1.42	1.23	1.57	1.07	1.32

Table 6. Correlation coefficient between safflower growth and yield parameters with seed yield under different green-manures and N : P levels and their interaction

Parameters	Green-manures	NP levels	GM × NP interaction
Seed yield of safflower/ha			
Plant height	0.938**	0.980**	0.912**
Leaf-area index	0.886*	0.995**	0.833*
Total dry-matter production	0.982**	0.977**	0.957**
Primary branches	0.940**	0.986**	0.942**
Secondary branches	0.980**	0.988**	0.964**
Number of capsules/plant	0.979**	0.985**	0.966**
Seed weight/plant	0.990**	0.950**	0.980**
1,000-seed weight	0.988**	0.924**	0.940**

nificant. The higher N uptake was observed with recommended dose of N and P (40 : 40 kg N : P₂O₅ kg/ha) when compared to no-fertilizer treatment. The lowest N uptake was recorded with no-fertilizer treatment. Among the interactions, sunnhemp GM with application of 40 : 40 kg N : P₂O₅/ha (GM₁F₄) to safflower recorded significantly higher N uptake than the other combinations (Fig. 2). Phosphorus uptake by safflower was significantly higher in all the green manures than fallow treatment. Among the graded levels of N and P, the highest P uptake was recorded with recommended doses of N and P on pooled basis when compared to all other NP levels. Among the interactions, significantly higher P uptake was recorded in cowpea GM with recommended dose of N and P fertilizer compared to the other treatment combinations. However, sunnhemp GM with recommended dose of N and P (GM₁F₄) remained on par with the former treatment. The addition of higher quantity of easily decomposable phytomass might have enhanced microbial activity leading to higher nutrient uptake by the crop, as evident from higher dehydrogenase and phosphatase activities (Table 7). Similar results were reported by Viridi *et al.* (2005).

Effect of in-situ leguminous green manures and NP levels on soil enzymatic activity

At 60 DAS, among the green manures, incorporation of sunnhemp recorded significantly higher dehydrogenase activity than fallow (Table 7). Among the NP levels, significantly higher dehydrogenase activity in soil was re-

corded with the application of 40 : 40 kg N : P₂O₅ kg/ha when compared to all lower NP levels. The lowest dehydrogenase activity was recorded with no-fertilizer treatment. Among GM × NP interactions, the higher dehydrogenase activity was recorded in sunnhemp GM along with 40 : 40 kg N : P₂O₅ kg/ha (GM₁F₄) compared with all other combinations except GM₃F₄. The lowest dehydrogenase activity was recorded with fallow treatment applied no-fertilizer (GM₄F₁). With regard to the phosphatase activity, an incorporation of cowpea recorded significantly higher phosphatase activity. The application of 40 : 40 kg N : P₂O₅ kg/ha was recorded significantly higher phosphatase activity in soil when compared to all lower NP levels. Among GM × NP interactions, significantly higher phosphatase activity was recorded in cowpea GM-applied with 40 : 40 kg N : P₂O₅ kg/ha (GM₃F₄) compared with all the other combinations. The variation in microbial activities could be attributed to the variations in phytomass, biomass and nutrient accumulation by green manures and external apply of balanced fertilizers. The results are in agreement with the findings of Walia and Kler (2007).

Thus, the study clearly indicates that cowpea and sunnhemp green manures saved N and P to the tune of 50%, while greengram GM saved 25% of N and P to the succeeding safflower. Further, the *in-situ* green manuring of cowpea/sunnhemp in *kharif* season as catch crop and its incorporation (at 55 DAS) and before sowing of safflower in *rabi* with higher dose of N : P (40 : 40 N : P₂O₅ kg/ha) enhanced seed yield (1.57/1.42 t/ha), net returns

Table 5. Effect of *in-situ* green-manuring and N : P levels on dehydrogenase and phosphatase activity of soil at 60 days after sowing (pooled data of 2 years)

Treatment	Dehydrogenase activity (µg TPF/g of soil/day)				Mean	Phosphatase activity (µg of pnp/g of soil/hr)				Mean
	Main plots (green-manures)					Main plots (green-manures)				
	Sunnhemp	green-gram	Cowpea	Fallow		Sunnhemp	Green gram	Cowpea	Fallow	
0:0 N:P kg/ha	5.07	4.17	4.07	3.80	4.28	34.98	35.80	40.32	24.95	34.01
20:20 N:P kg/ha	5.65	4.48	4.34	4.06	4.63	39.68	37.48	45.54	30.50	38.30
30:30 N:P kg/ha	5.88	5.50	5.62	5.01	5.50	42.55	39.87	51.12	34.58	42.03
40:40 N:P kg/ha	6.71	5.92	6.70	5.32	6.16	50.31	43.28	60.03	39.87	48.37
Sub plots (N : P levels) Mean	5.83	5.02	5.18	4.55		41.88	39.11	49.25	32.47	
	SEm±			CD (P=0.05)		SEm±			CD (P=0.05)	
Main plot	0.046			0.16		0.19			0.65	
Subplot	0.049			0.14		0.23			0.67	
Interaction	0.099			0.29		0.46			1.34	

(₹30,227/₹26,263) and benefit: cost ratio (3.85/3.45) when compared to fallow-safflower system with higher dose of N:P (40:40 N:P₂O₅ kg/ha).

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