

Effect of nitrogen, phosphorus and sulphur fertilization on productivity, nutrient-use efficiency and economics of safflower (*Carthamus tinctorius*) under late-sown condition

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ABSTRACT

A field experiment was conducted at Varanasi during winter (*rabi*) seasons of 2009–10 and 2010–11 to study the effect of nitrogen, phosphorus and sulphur fertilization on productivity, nutrient-use efficiency and economics of safflower (*Carthamus tinctorius* L.) under late-sown condition. An application of 80 kg N/ha, 80 kg P₂O₅/ha and 60 kg S/ha significantly increased the seed yield with concomitant increase in yield attributes. Enhanced supply of N or P or S reduced the agronomic efficiency (AE) apparent recovery (AR) and physiological efficiency (PE) and the highest efficiency of these respective nutrients was recorded with 40 kg N, 40 kg P₂O₅ and 20 kg S/ha, and the lowest with 80 kg N/ha, 80 kg P₂O₅/ha and 60 kg S/ha. Maximum net returns/ha were obtained with 80 kg N (₹29,400/ha), 80 kg P₂O₅ (₹25,500/ha) and 20 kg S/ha (₹22,800/ha). The seed yield response to tested levels of nitrogen, phosphorus and sulphur was found quadratic. The economic optimum dose of nitrogen, phosphorus and sulphur for safflower was calculated from regression equations to be 79.0, 77.7 and 53.1 kg/ha respectively.

Key words : Agronomic efficiency, Apparent recovery, Crop productivity, Economics, Nutrient uptake, Physiological efficiency, Safflower, Seed yield

Safflower is an important oilseed crop of the world. In India, it is grown in winter season and accounts for about 8.0% of the value of total oilseeds produce. Safflower has a deep root system and thus, can capture leached nutrients below the rooting-zone of other crops (Tanaka and Merrill, 1998). In northern India, sowing of safflower gets delayed due to late harvesting of long-duration rice crop as well as in areas where moisture from rice fields cannot be receded out in time. Late sown safflower is exposed to high temperature during the reproductive phase, along with reduced growing season and consequently, results in reduced growth and productivity. In recent years, nutrient management is one of the critical inputs in achieving high productivity of safflower (Mundel *et al.*, 2004). The crop's response to N is generally greater than that of other nutrients (Weiss, 2000). However, the amount of commercial fertilizer required for safflower production depends on the yield target, the place of safflower in the crop rotation and on the other crops included in the rotation cycle (Berglund *et al.*, 2007). Safflower requires 5 kg/ha of N to produce

100 kg/ha of seed (Mundel *et al.*, 2004). The deficiency of secondary and micronutrients is wide spread in many parts of the country due to cultivation of high-yielding varieties, intensive agriculture and increasing use of sulphur-free fertilizers in large quantities with concomitant decrease in use of organic manures. Oilseeds are energy-rich crops, so phosphorus and sulphur nutrition assumes greater importance in comparison to other nutrients. This necessitates rational application of these elements as they have becoming limiting factor for obtaining higher yields of several oilseed crops including safflower. Keeping these aspects in view, a field experiment was undertaken to study the effect of nitrogen, phosphorus and sulphur fertilization on productivity, nutrient-use efficiency and economics of safflower under late sown condition.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) seasons of 2009–10 and 2010–11 at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi of Eastern Uttar Pradesh. The Research Farm is located at 25°18' N latitude and 83°03' E longitude with an elevation of 128.93 m above mean sea-level. The experimental soil

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was sandy clay loam (Order Inceptisol, Type Ustochrept). The pH of soil was 7.6 with organic carbon 0.37 and 0.39%, available nitrogen 216.5 and 215.1 kg/ha, available phosphorus 20.2 and 18.5 kg/ha and available sulphur 23.4 and 22.7 kg/ha during the first and second years of experimentation respectively. The experiment was laid out with 3 levels of nitrogen (0, 40 and 80 kg/ha), 3 levels of phosphorus (0, 40 and 80 kg/ha) and 4 levels of sulphur (0, 20, 40 and 60 kg/ha) in split-plot design keeping combinations of N and P in the main plots and sulphur in sub-plots with 3 replications. Nitrogen, phosphorus and sulphur were applied as per treatment through urea, diammonium phosphate (DAP) and elemental sulphur respectively. Safflower variety 'HUS 305' was sown uniformly @ 15 kg/ha in rows 45 cm apart on 4 and 7 November and harvested on 11 and 14 April during 2009–10 and 2010–11 respectively. Irrigation was applied to safflower at 35, 75, and 110 days after sowing (DAS) through check-basin method by electric tube-well up to 5.0 cm depth/plots of above soil surface. There were no incidents of severe insect pests or diseases during any of these years. The experimental plot size was 22.5 m², being 4.5 m in length and 5.0 m in width. The meteorological data, viz. precipitation (49.0 and 22.1 mm) and evapotranspiration (85.8 and 74.2 mm) was recorded during crop growing season in 2009–10 and 2010–11 respectively. Observations on yield attributes and yield were recorded at harvest and the data were statistically analysed as per standard protocol. Seed samples were dried and grounded in Willey mill and used for chemical analysis. Nitrogen in the grounded seed and stover samples and P as well as S in the extracts (HNO₃-HClO₄) were determined by modified Kjeldahl's method for N, Vandomolybdate phosphoric yellow colour method for P and turbidimetric method for S. Nutrient uptake was calculated by determined nutrient concentration in relation to dry matter production. The protein content in seed was calculated by multiplying the per cent nitrogen in seed with a factor 6.25. The percentage of oil content in seeds was determined by solvent extraction method in Soxhlet's apparatus with petroleum ether (BP 40-60 °C) as solvent (AOAC, 1980). Iodine value was estimated by titrating the mixture of known amount of oil, carbon tetrachloride and potassium iodide solutions against the standard sodium thiosulphate using starch as indicator (Kumar and Chauhan, 2010). Since data obtained over the years done at same experimental site followed the homogeneity test, pooling was done over the seasons and the mean data are given. The economics was computed by using market prices of inputs and outputs. Net return was calculated by subtracting cost of cultivation from gross return. Net benefit: cost (B: C) ratio was worked as ratio of net return to that of cost of cultiva-

tion. Nutrient use efficiency of N, P and S were also calculated based on the formulae given by Duncan and Baligar (1990).

The quadratic curve estimation of N or P or S levels (kg/ha) and seed yield (kg/ha) data was done with the Microsoft office excel 2007 and economic optimum dose of N or P or S calculated by regression equation.

Economic optimum dose = (Output/Input)-b/2c

RESULTS AND DISCUSSION

Yield attributes, yield and quality

Nitrogen and phosphorus application induced significant increase in yield attributes, viz. capsules/plant, seed weight/head and 1,000-seed weight of safflower (Table 1). Nitrogen and phosphorus application up to 40 kg/ha recorded significant increase in capsules/plant, seed weight/head and 1,000-seeds weight over the control. Nitrogen and phosphorus application beyond 40 kg N/ha caused improvement in yield attributes but increase was statistically insignificant. As regard the sulphur application, sulphur applied at 60 kg S/ha produced higher number of capsules/plant, seed weight/head and 1,000-seed weight than 40 kg S/ha, though these 2 sulphur levels remained statistically comparable. This was due to adequate application of nitrogen and phosphorus which were directly involved in cell multiplication and vigorous root system development for effective absorption of applied nutrients, whereas sulphur resembles nitrogen in being able to improve cell division, cell elongation as well as having a favourable effect in chlorophyll synthesis.

Favourable effect of N and P application on the yield attributes further got reflected on the seed yield. The seed yield with N and P application recorded significant increase up to 40 kg/ha (Table 1). Further increase in N and P level did not produce perceptible increase in seed yield. On pooled mean data basis, the percent increase in seed yields with 40 and 80 kg N/ha was 44.6 and 60.5% over the control respectively. The increase in seed yields at 40 and 80 kg P₂O₅/ha over control was 25.4 and 33.3% respectively. Successive increase in the S application produced significant in seed yield up to 40 kg S/ha. Subsequent increase in the S application from 40 to 60 kg S/ha improved the seed yield, however, it was of the same order statistically. The mean seed yield of 2.30 t/ha at 60 kg S/ha was produced which was 2.2, 5.5 and 19.8% higher than that recorded at 40 kg/ha, 20 kg S/ha and control respectively.

Nitrogen and phosphorus application brought about significant improvement in stover yield, harvest index, oil and protein content of safflower. Nitrogen up to 40 kg N/ha and phosphorus up to 40 kg P₂O₅/ha appeared optimum dose, as that level improved the stover yield, harvest in-

dex, oil and protein content significantly over the control respectively (Table 1). The subsequent higher level of N and P (80 kg/ha) was statistically at par with 40 kg/ha in improving stover yield and harvest index. Significant effect of sulphur on stover yield, harvest index, oil and protein content was observed up to 40 kg S/ha, although there was improvement in the aforesaid parameters with subsequent increase in S levels. Nitrogen caused favourable effect on plant growth and development due to proper partitioning of the photosynthates from source to sink. These results confirm the findings of Hussain *et al.* (2011) in sunflower. The oil content increased successively with increase in P level, probably because it is a constituent of phospholipid and is essential for its synthesis. The increase in oil content with increase in S level might be due to the involvement of sulphur in electron-transport chain (Margatham and Chellamuthu, 2000).

Nitrogen and phosphorus application failed to cause significant effect on Iodine value of oil (Table 1). The maximum Iodine value was found with higher level of nitrogen and phosphorus, and the minimum with control. Application of 40 and 60 kg S/ha though remained at par recorded significantly higher iodine value than 20 kg S/ha and control respectively.

Nutrient uptake

There was a significant increase in the N, P, S and total N, P and S uptake with the application of N, P and S. The N, P and S uptake increased significantly with subse-

quent increase in N and P application up to 80 kg/ha. Sulphur application caused significant increase in N, P and S uptake up to 60 kg/ha (Table 2). The increase in N, P, S and total uptake in safflower due to 40 kg N/ha was 16.5, 15.7, 10.8, 15.5% and 80 kg N/ha was 22.7, 22.2, 21.1, 22.4% over control respectively. Application of 80 kg P₂O₅/ha improved the N uptake by 24.1 and 6.0%; P uptake by 35.3 and 14.8%; S uptake by 23.8 and 11.0% and total NPS uptake by 25.7 and 8.1% over 40 kg P₂O₅/ha and the control respectively. Sulphur application with 60 kg/ha increased uptake of N by 5.8, 14.4 and 21.8%; uptake of P by 7.0, 19.1 and 48.3%; uptake of S by 10.8, 18.9 and 38.6% and uptake of total N, P and S by 6.9, 15.9 and 30.6% over 40, 20 kg S/ha and control respectively. Nutrient uptake increased due to higher dry-matter accumulation. These results are in conformity with the findings of Mohd *et al.* (1995) and Dineshkar and Babulkar (1998) in safflower.

Agronomic efficiency

Agronomic efficiency was improved by 5.87 kg seed added/kg N with application 40 kg N/ha compared with 80 kg N/ha. Further, the application of 40 kg P₂O₅/ha enhanced the agronomic efficiency by 3.74 kg seed added/kg P₂O₅ compared with 80 kg P₂O₅/ha. Agronomic efficiency increased from 6.36 kg seed added at 20 kg S/ha to 13.05 kg seed added at 60 kg S/ha. Application of 20 kg S/ha enhanced the agronomic efficiency by 4.99 and 6.69 kg seed added/kg S compared with 40 and 60 kg S/ha (Table 2).

Table 1. Effect of nitrogen, phosphorus and sulphur levels on yield attributes, yield and quality of safflower (pooled mean data of 2 years)

Treatment	Capsules/ plant	Seeds weight/head (g)	1,000- seed weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Oil content (%)	Protein content (%)	Iodine value
<i>Nitrogen (kg/ha)</i>									
Control	22.8	0.69	43.6	1.57	4.00	28.9	32.4	14.6	136.9
40	33.5	0.92	60.5	2.27	5.71	30.2	33.3	15.6	137.4
80	38.2	0.98	67.8	2.52	6.06	30.4	33.5	16.5	137.8
SEm±	1.73	0.03	2.14	0.10	0.15	0.19	0.23	0.16	0.72
CD (P=0.05)	5.42	0.10	6.64	0.28	0.43	0.55	0.74	0.51	NS
<i>Phosphorus (kg/ha)</i>									
Control	24.5	0.71	47.0	1.77	4.43	29.6	31.9	14.9	136.5
40	30.0	0.82	53.6	2.22	5.52	30.2	33.8	15.6	137.7
80	36.6	0.96	65.1	2.36	5.81	31.0	34.0	15.4	138.3
SEm±	1.73	0.03	2.14	0.10	0.15	0.19	0.23	0.16	0.72
CD (P=0.05)	5.42	0.10	6.64	0.27	0.43	0.55	0.74	0.51	NS
<i>Sulphur (kg/ha)</i>									
Control	27.2	0.77	49.5	1.92	4.74	30.1	31.4	15.0	136.9
20	28.7	0.84	51.7	2.18	5.29	30.6	33.1	15.4	137.2
40	31.9	0.87	57.4	2.25	5/38	31.1	34.4	16.0	137.7
60	34.6	0.94	63.3	2.30	5.63	31.1	34.7	15.9	139.1
SEm±	1.03	0.02	1.31	0.06	0.11	0.15	0.17	0.12	0.56
CD (P=0.05)	2.96	0.06	4.13	0.18	0.31	0.46	0.53	0.35	1.81

Apparent recovery

Application of 40 kg N/ha enhanced the apparent recovery by 9.37% compared with 80 kg N/ha. Apparent recovery was improved by 7.0% more with application 40 kg P₂O₅/ha compared with 80 kg P₂O₅/ha. Apparent recovery of sulphur was reduced from 27.50% at 20 kg S/ha to 25.08% at 60 kg S/ha application. Apparent recovery of sulphur was enhanced at 20 kg S/ha by 0.37 and 2.42% compared with 40 and 60 kg S/ha (Table 2).

Physiological efficiency

Physiological efficiency of N decreased by 2.06 kg

seed/kg N absorbed at 80 kg N/ha compared to 40 kg N/ha. The highest physiological efficiency 79.9 kg seed/kg N was recorded with 40 kg N/ha (Table 2). Application of 40 kg P₂O₅/ha absorbed the physiological efficiency by 3.01 kg seed/kg P₂O₅ compared with 80 kg P₂O₅/ha. Physiological efficiency absorbed from 47.29 at 20 kg S/ha to 25.30 at 60 kg S/ha. Application of 20 kg S/ha absorbed the physiological efficiency by 17.72 and 21.99 kg seed/kg S compared with 40 and 60 kg S/ha.

Economics

The cost of cultivation varied according to different

Table 2. Effect of nitrogen, phosphorus and sulphur levels on nutrient uptake and efficiency indices of safflower (mean data of 2 years)

Treatment	Nutrient uptake in seed + stover (kg/ha)				AE _{N or P or S} (kg seed/kg _{N or P or S})	AR _{N or P or S} (%)	PE _{N or P or S} (kg seed/kg _{N or P or S})
	Nitrogen	Phosphorus	Sulphur	Total			
<i>Nitrogen (kg/ha)</i>							
Control	54.15	10.80	11.60	76.55	-	-	-
40	63.10	12.50	12.85	88.45	17.72	25.13	79.89
80	66.45	13.20	14.05	93.70	11.85	15.76	77.83
SEm±	0.44	0.18	0.27	1.23	-	-	-
CD (P=0.05)	1.38	0.62	0.86	3.49	-	-	-
<i>Phosphorus (kg/ha)</i>							
Control	56.10	11.75	12.60	80.45	-	-	-
40	65.65	13.85	14.05	93.55	11.14	23.88	46.68
80	69.60	15.90	15.60	101.10	7.40	16.88	43.67
SEm±	0.44	0.18	0.27	1.23	-	-	-
CD (P=0.05)	1.38	0.62	0.86	3.49	-	-	-
<i>Sulphur (kg/ha)</i>							
Control	60.65	12.85	15.15	88.65	-	-	-
20	66.15	16.00	17.65	99.80	13.05	27.50	47.29
40	71.50	17.80	18.95	108.25	8.06	27.13	29.57
60	75.70	19.05	21.00	115.75	6.36	25.08	25.30
SEm±	0.31	0.12	0.20	0.96	-	-	-
CD (P=0.05)	0.97	0.39	0.64	2.92	-	-	-

AE_{N or P or S}; AR_{N or P or S}; PE_{N or P or S}

Table 3. Effect of nitrogen, phosphorus and sulphur levels on economics of safflower (mean data of 2 years)

Treatment	Cost of cultivation (× 10 ³ ₹/ha)	Gross returns (× 10 ³ ₹/ha)	Net returns (× 10 ³ ₹/ha)	Benefit: cost ratio	Crop productivity (kg/ha/day)	Crop profitability (₹/ha/day)
<i>Nitrogen (kg/ha)</i>						
Control	12.2	26.3	14.1	1.16	9.9	88.9
40	12.5	38.2	25.7	2.06	14.3	161.9
80	12.8	42.3	29.4	2.31	15.8	185.4
<i>Phosphorus (kg/ha)</i>						
Control	12.2	29.7	17.5	1.44	11.1	110.3
40	13.5	37.2	23.7	1.77	13.9	149.5
80	14.1	39.6	25.5	1.81	14.9	160.7
<i>Sulphur (kg/ha)</i>						
Control	12.2	32.3	20.1	1.65	12.1	126.3
20	13.8	36.6	22.8	1.65	13.7	143.6
40	15.5	37.7	22.2	1.44	14.1	139.9
60	17.1	38.7	21.6	1.27	14.5	135.9

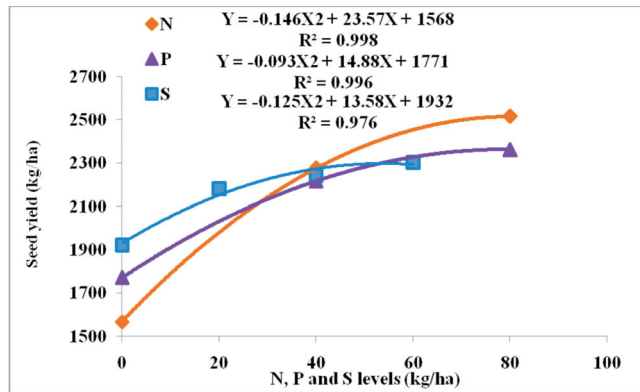


Fig. 1. Quadratic relationship between N, P and S levels with seed yield

doses of nitrogen, phosphorus and sulphur. Maximum gross return, net return, benefit: cost ratio, crop productivity and profitability were obtained with 80 kg N/ha and 80 kg P₂O₅/ha. Net return and benefit: cost ratio recorded continuous increase with increasing level of N and P but the maximum increase was recorded between the control and 40 kg/ha. In case of sulphur, maximum gross return and crop productivity were recorded with the application of 60 kg S/ha, whereas the highest net return, benefit: cost ratio and crop profitability were recorded with 20 kg/ha (Table 3). This behaviour of gross return, net return, benefit: cost ratio, crop productivity and profitability may be attributed to yield trend due to N, P and S application and relative cost of inputs in relation to output. These results confirm the findings reported by Hussain *et al.* (2011) in sunflower.

Response equation and optimum dose of nitrogen, phosphorus and sulphur

The response equations revealed that response of nitrogen, phosphorus and sulphur on seed yield of safflower was quadratic, indicating the operation of the law of diminishing return. The correlation coefficient (0.998, 0.996 and 0.976) between nitrogen, phosphorus and sulphur

with seed yield was showed that, it was highly correlated. From the regression equation of safflower, the economic optimum dose of N, P₂O₅ and sulphur were worked out to be 79.0, 77.7 and 53.1 kg/ha respectively.

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