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Effect of nitrogen and sulphur levels on yield, nutrient uptake and their use efficiency safflower (*Carthamus tinctorius* L.) crop

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Abstract

The experiment was carried out during *rabi* season during years 2022-23 and 2023-24 at the instructional Farm of Krishi Vigyan Kendra, Balod Chhattisgarh. The experiment was laid out in split plot design with four nitrogen levels (N_0 , N_{30} , N_{60} and N_{90} kg N ha⁻¹) and three sulphur levels (S_0 , S_{20} and S_{40} kg S ha⁻¹) comprising twelve treatment combinations with three replications. The soil of the experimental site found neutral to slightly alkaline in reaction (pH 7.13), non-saline (0.22 dS m⁻¹) in nature, medium in organic carbon (5.13 g kg⁻¹), low in available nitrogen (217.12 kg N ha⁻¹), medium in phosphorus (15.30 kg P₂O₅ ha⁻¹), high in available potassium (409.12 kg K₂O ha⁻¹), medium in available sulphur (15.26 kg S ha⁻¹) and clayey in texture (46%). Applied treatments nitrogen and sulphur levels highest seed yield, stover yield and nutrient uptake were recorded with 90 kg N ha⁻¹ & 40 kg S ha⁻¹. In applied N and S levels highest NUE 30 kg N ha⁻¹ & 20 kg S ha⁻¹ and SUE 90 kg N ha⁻¹ & 20 kg S ha⁻¹ and in lowest was found under control.

Keywords: NUE, SUE, Nutrient uptake, seed and stover yield

Introduction

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) [18]. Nutrient management is one of the critical inputs in achieving high productivity of safflower (Mundel *et al.*, 2004) [9]. The crop's response to N is generally greater than that of other nutrients (Weiss, 2000) [20]. 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) [1]. Safflower requires 5 kg/ha of N to produce 100 kg/ha of seed (Mundel *et al.*, 2004) [9]. 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. Sulphur is also essential for the formation of chlorophyll and in the formation of vitamins and enzymes required for the plant to conduct its biochemical processes (Jat *et al.*, 2017) [6]. Sulphur plays an important role in the nutrition of oil seed crop and act as a constituent of sulphur containing amino acids cysteine, cysteine and methionine (Parmar *et al.*, 2018) [13].

Nutrient use efficiencies have been used widely as a measure of the capacity of a plant to acquire and utilize nutrients and may be broken down mechanistically in to the ability to acquire nutrients from the soil (uptake efficiency) and the ability to utilize accumulated nutrients for biomass production or yield formation (use efficiency).

Materials and Methods

The experiment was carried out during Rabi season of 2022-23 & 2023-24 at the instructional Farm of Krishi vigyan Kendra, Balod Chhattisgarh which is located at between 20°80' North latitude and 81°24' East longitudes with an altitude of 324 m above mean sea level. This area is situated on state highway No. 7 and carried out with 12 treatments and 3 replications were

carried out along with four levels of Nitrogen (0, 30, 60 & 90) kg/ha and three levels of Sulphur (0, 20 & 40) kg/ha. Applied seed rate was 12 kg/ha, and the basal dose (0:60:30) NPK kg/ha and the spacing at 45x15cm. pH determines by, Glass electrode pH meter (Piper, 1967) [14], EC is Salt bridge by Black (1965) [2], OC. Is Rapid titration method (Walkely and Black, 1934) [19], Available nitrogen determined by Alkaline permanganate method (Subbiah and Asija, 1956) [16], available sulphur was determined by Turbid metric method given by Chesnin and Yien (1951) [3]. To carry out chemical analysis of plant, the randomly selected plot wise.

Results and Discussion

Seed and stover yield

The data on seed and stover yield of safflower as affected by application of different nitrogen and sulphur levels are presented in Table 1. The maximum seed and stover yield (17.91 & 40.46 q ha⁻¹, respectively) were recorded under N₉₀ followed by N₆₀ and N₃₀ on mean basis of both the years. In regards to sulphur levels, treatment S₄₀ observed the maximum seed and stover yield (15.33 & 39.93 q ha⁻¹, respectively). However, the minimum seed and stover yield were observed under control plot on mean basis of both the years. The increase in seed yield and stover yield with applied levels of nitrogen and sulphur to crop shown cumulative effect on increased yield attributing characters viz., no. of capitula plant⁻¹ and no. of seeds capitulum⁻¹ might have resulted in the production of higher seed yield. Similar findings are also confirmed by Singh and Singh (2013) [15], Nathan *et al.* (2017) [11], (Divya, 2019) [4], and Patel *et al.* (2022) [12]. The interaction between N₉₀ x S₄₀ was registered significantly higher seed and stover yield were as compared to others, but it was at par with interaction between N₉₀ x S₂₀. The increase in yield might be due to more accumulation of amino acid and amide substances and their translocations to the reproductive organs which influenced growth and yield due to application on nitrogen and sulphur (Dongarkar, 2005) [5].

Nutrient uptake

The data on nutrient uptake of safflower as affected by application of different nitrogen and sulphur levels are presented in Table 2, 3, 4 and 5.

There was a significant increase in the N, P, K, S and total N, P, K and S uptake with the application of N and S. The N, P, K and S uptake increased significantly with subsequent increase in Nitrogen and Sulphur application up to 90 and 40 kg/ha. over control respectively. Nutrient uptake increased due to higher dry-matter accumulation, improved permeability coupled with better absorption due to better availability of nutrients in the soil solution (Singh and Singh, 2013) [15]. Each higher level of

nitrogen and sulphur significantly improved the nutrient uptake. Similar trend in nutrient uptake pattern of nitrogen and sulphur was noticed by Patel *et al.*, (2023).

Nitrogen use efficiency of safflower crop (%)

The data on N and S use efficiency of safflower as affected by different N and S levels are presented in Table 7.

NUE of safflower crop influenced significantly with applied nitrogen levels over control. The maximum NUE was found under N₃₀ followed by N₆₀ and N₉₀. The minimum NUE was observed under N₉₀. As the N application increases then NUE decreases due to efficient use of applied N at lower level and as N application increased the proportionate amount of N uptake decreased. Thus, the reduction of N fertilizer input and improved NUE are crucial for sustainable production. Similar results of were found by Patel *et al.* (2022) [12], Srivastav *et al.* (2017) and Manjeet & Praveen (2018) [8] and incase of sulphur levels NUE of safflower increased steeply with increasing application rates of sulphur. The significantly maximum NUE was recorded under S₄₀ followed by S₂₀. The minimum NUE was noted under control. The increase in S levels as well as increased the crop yields resulted higher NUE. Similar results of were found by Patel *et al.* (2022) [12], Koutrobas *et al.* (2008), Murtaza *et al.* (2017) [10] and Telebbeigi *et al.* (2018).

Sulphur use efficiency of safflower crop (%)

SUE of safflower crop influenced significantly with applied nitrogen levels over control. The maximum SUE was found under N₉₀ followed by N₆₀ and N₃₀ during both the years and on mean basis. The minimum SUE was observed under control. SUE increases with nitrogenous (N) fertilizers primarily due to a synergistic relationship where S is required for proper nitrogen metabolism, enabling the conversion of inorganic nitrogen into plant proteins. Adequate nitrogen promotes vigorous growth, which increases the crop's uptake capacity for sulphur, while sulphur helps prevent N loss. Similar results of were found by Patel *et al.* (2022) [12] and incase of sulphur levels safflower crop influenced significantly with applied sulphur levels over control. The maximum SUE was recorded under S₂₀ followed by S₄₀. The minimum SUE was noted under control during. SUE decreases with increasing sulphur fertilizer application due to efficient use of applied S at lower levels, slow oxidation of elemental sulfur, and excessive soil application exceeding crop uptake, which leads to luxury consumption and potential antagonistic interactions with other nutrients. Enhanced supply of S fertilizer reduced the all S efficiency and the highest efficiency of these respective nutrients. Similar result was found by Patel *et al.* (2022) [12].

Table 1: Effect of nitrogen and sulphur levels on seed & stover Yield (q ha⁻¹) of safflower

Treatments	Seed Yield (q ha ⁻¹)				Stover Yield (q ha ⁻¹)		
	2022-23	2023-24	Mean	Yield increase (%) over control	2022-23	2023-24	Mean
Nitrogen levels (kg ha ⁻¹)							
N ₀	10.89	11.26	11.07	-	29.73	31.83	30.78
N ₃₀	13.67	14.70	14.19	25.16	35.27	37.37	36.32
N ₆₀	15.47	16.14	15.80	37.47	37.25	39.34	38.05
N ₉₀	17.40	18.41	17.91	53.68	39.59	41.33	40.46
SEm ±	0.54	0.65	0.50		0.56	0.57	0.55
CD (P=0.05)	1.88	2.25	1.73		1.95	1.98	1.91
Sulphur levels (kg ha ⁻¹)							
S ₀	13.56	14.31	13.94	-	34.77	36.81	35.73
S ₂₀	14.62	15.29	14.96	9.90	35.64	37.56	36.54
S ₄₀	14.89	15.78	15.33	15.45	35.97	38.02	36.93

SEm ±	0.16	0.16	0.13		0.30	0.19	0.24
CD (P=0.05)	0.47	0.47	0.38		0.89	0.57	0.71
Combined effect of nitrogen and sulphur levels (Interaction N x S)							
Treatments	Seed Yield (q ha ⁻¹)			Stover Yield (q ha ⁻¹)			
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	
N ₀ S ₀	10.70	10.72	10.71	20.29	31.40	30.35	
N ₀ S ₂₀	10.90	11.05	10.97	29.82	31.92	30.87	
N ₀ S ₄₀	11.06	12.02	11.54	30.05	32.15	37.10	
N ₃₀ S ₀	12.77	14.14	13.46	34.25	36.35	35.30	
N ₃₀ S ₂₀	14.01	14.97	14.49	35.60	37.70	36.65	
N ₃₀ S ₄₀	14.25	14.99	14.61	35.97	38.07	37.02	
N ₆₀ S ₀	14.93	15.68	15.31	36.77	38.86	37.57	
N ₆₀ S ₂₀	15.71	16.18	15.95	37.16	39.25	37.95	
N ₆₀ S ₄₀	15.75	16.56	16.16	37.83	39.92	38.62	
N ₉₀ S ₀	15.83	16.72	16.28	38.75	40.65	39.70	
N ₉₀ S ₂₀	17.87	18.97	18.42	39.99	41.39	40.69	
N ₉₀ S ₄₀	18.50	19.55	19.03	40.05	41.95	40.99	
SEm ±	0.63	0.72	0.56	0.82	0.69	0.73	
CD(P=0.05)	2.10	2.44	1.89	NS	NS	NS	

Table 2: Effect of nitrogen and sulphur levels on nitrogen uptake (kg ha⁻¹) of safflower

Treatments	N Uptake by Seed (Kg/ha)			N Uptake by Stover (Kg/ha)			Total N Uptake (Kg/ha)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Nitrogen levels (kg ha⁻¹)									
N ₀	22.83	23.40	23.11	17.97	18.88	18.43	40.80	42.28	41.54
N ₃₀	29.06	31.17	30.12	21.90	23.87	22.89	50.96	55.05	53.00
N ₆₀	33.24	34.57	33.91	24.13	25.89	25.01	57.37	60.46	58.91
N ₉₀	37.12	38.72	37.92	26.19	28.02	27.10	63.21	66.74	64.97
SEm ±	1.05	0.72	0.67	0.46	0.36	0.31	1.03	0.94	0.74
CD (P=0.05)	3.65	2.49	2.32	1.61	1.24	1.07	3.56	3.26	2.55
Sulphur levels (kg ha⁻¹)									
S ₀	28.54	30.41	29.48	21.71	23.45	22.58 c	50.25	53.86	52.06
S ₂₀	30.79	32.14	31.47	22.46	24.03	23.25	53.18	56.17	54.68
S ₄₀	32.35	33.34	32.85	23.48	25.01	24.25	55.83	58.35	57.09
SEm ±	0.39	0.33	0.31	0.29	0.27	0.20	0.48	0.55	0.47
CD (P=0.05)	1.16	0.99	0.92	0.87	0.80	0.59	1.44	1.64	1.41
(Interaction N x S)									
SEm ±	1.31	0.98	0.91	0.75	0.64	0.50	1.41	1.44	1.20
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Effect of nitrogen and sulphur levels on phosphorus uptake (kg ha⁻¹) of safflower

Treatments	P Uptake by Seed (Kg/ha)			P Uptake by Stover (Kg/ha)			Total P Uptake (Kg/ha)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Nitrogen levels (kg ha⁻¹)									
N ₀	5.02	5.39	5.21	6.49	7.24	6.87	11.52	12.63	12.07
N ₃₀	6.03	6.75	6.39	8.08	8.93	8.50	14.11	15.68	14.90
N ₆₀	6.56	7.62	7.09	9.15	9.35	9.25	15.71	16.97	16.34
N ₉₀	7.48	9.00	8.24	10.39	10.99	10.69	17.85	19.99	18.92
SEm ±	0.27	0.37	0.26	0.11	0.23	0.22	0.31	0.50	0.44
CD (P=0.05)	0.93	1.28	0.90	0.39	0.79	0.75	1.09	1.73	1.52
Sulphur levels (kg ha⁻¹)									
S ₀	5.69	6.58	6.14	7.97	8.75	8.36	13.65	15.33	14.49
S ₂₀	6.35	7.31	6.83	8.60	9.09	8.84	14.95	16.40	15.68
S ₄₀	6.78	7.68	7.23	9.01	9.55	9.28	15.79	17.22	16.51
SEm ±	0.14	0.11	0.12	0.12	0.15	0.14	0.17	0.20	0.18
CD (P=0.05)	0.42	0.34	0.35	0.36	0.45	0.43	0.52	0.58	0.54
(Interaction N x S)									
SEm ±	0.39	0.43	0.35	0.26	0.38	0.36	0.47	0.63	0.57
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Effect of nitrogen and sulphur levels on potassium uptake (kg ha⁻¹) of safflower

Treatments	K Uptake by Seed (Kg/ha)			K Uptake by Stover (Kg/ha)			Total K Uptake (Kg/ha)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Nitrogen levels (kg ha⁻¹)									
N ₀	9.01	9.32	9.17	45.86	50.36	48.11	54.87	59.68	57.27
N ₃₀	10.40	11.12	10.76	55.07	61.13	58.10	65.46	72.25	68.86
N ₆₀	10.89	11.88	11.39	59.40	68.28	63.84	70.30	80.17	75.23
N ₉₀	13.13	13.82	13.47	63.79	71.05	67.42	76.91	84.98	80.89
SEm ±	0.37	0.56	0.39	0.93	0.41	0.60	0.81	0.88	0.78
CD (P=0.05)	1.27	1.92	1.36	3.21	1.43	2.08	2.81	3.04	2.70
Sulphur levels (kg ha⁻¹)									
S ₀	10.01	10.85	10.43	54.58	61.06	57.82	64.59	71.91	68.25
S ₂₀	10.73	11.48	11.11	56.03	62.50	59.27	66.77	73.98	70.37
S ₄₀	11.83	12.28	12.06	57.47	64.55	61.01	69.30	76.91	73.07
SEm ±	0.26	0.25	0.19	0.47	0.40	0.23	0.44	0.59	0.36
CD (P=0.05)	0.77	0.76	0.58	1.40	1.21	0.68	1.33	1.77	1.08
(Interaction N x S)									
SEm ±	0.63	0.75	0.55	1.31	0.91	0.75	1.20	1.47	1.06
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Effect of nitrogen and sulphur levels on sulphur uptake (kg ha⁻¹) of safflower

Treatments	S Uptake by Seed (Kg/ha)			S Uptake by Stover (Kg/ha)			Total S Uptake (Kg/ha)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Nitrogen levels (kg ha⁻¹)									
N ₀	2.74	2.89	2.81	6.98	7.40	7.19	9.72	10.29	10.00
N ₃₀	3.38	3.76	3.57	7.95	8.32	8.14	11.33	12.08	11.70
N ₆₀	3.75	4.01	3.88	8.21	8.89	8.55	11.96	12.90	12.43
N ₉₀	4.23	5.06	4.64	9.35	10.17	9.76	13.58	15.23	14.40
SEm ±	0.14	0.21	0.13	0.33	0.20	0.26	0.35	0.31	0.28
CD (P=0.05)	0.47	0.73	0.44	1.13	0.69	0.89	1.21	1.07	0.98
Sulphur levels (kg ha⁻¹)									
S ₀	2.73	2.99	2.86	6.63	7.24	6.94	9.36	10.23	9.79
S ₂₀	3.67	4.02	3.85	8.32	8.83	8.58	12.00	12.86	12.43
S ₄₀	4.17	4.78	4.47	9.42	10.01	9.71	13.58	14.79	14.19
SEm ±	0.09	0.10	0.06	0.13	0.14	0.11	0.12	0.11	0.07
CD (P=0.05)	0.26	0.30	0.17	0.39	0.41	0.32	0.36	0.33	0.22
(Interaction N x S)									
SEm ±	0.22	0.29	0.17	0.42	0.34	0.34	0.43	0.38	0.32
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6: Effect of nitrogen and sulphur levels on NUE (%) and SUE (%) of safflower

Treatments	NUE (%)			SUE (%)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean
Nitrogen levels (kg ha⁻¹)						
N ₀	0.00	0.00	0.00	3.86	4.42	4.14
N ₃₀	33.85	42.54	38.20	6.49	7.30	6.90
N ₆₀	27.61	30.29	28.95	8.53	8.64	8.59
N ₉₀	24.90	27.17	26.03	12.10	13.54	12.82
Sulphur levels (kg ha⁻¹)						
S ₀	20.31	23.72	22.02	00.00	00.00	00.00
S ₂₀	25.48	28.79	24.87	12.66	14.11	13.39
S ₄₀	21.10	24.89	22.99	10.58	11.31	10.95

Conclusion

It is concluded that application of nitrogen at 90 kg N ha⁻¹ (N₄) and application of sulphur 40 kg S ha⁻¹ (S₃) has given more seed yield and dry matter production and higher nitrogen, phosphorus, potassium and sulphur uptake. But NUE decrease with increasing Nitrogenous fertilizers in levels of nitrogen and increasing with sulphur fertilizers levels and SUE increase with increasing Nitrogenous fertilizers in levels of nitrogen and decrease with sulphur fertilizers levels.

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