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Response of nitrogen and Sulphur levels on growth and yield of safflower (*Carthamus tinctorius* L.)

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Abstract
The experiment was carried out during *rabi* season during years 2019-20 and 2020-21 at the Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The experiment was laid out in factorial randomized block design with four nitrogen levels (N_0, N_{45}, N_{90} and N_{135} kg N ha^{-1}) and four Sulphur levels (S_0, S_{15}, S_{30} and S_{45} kg S ha^{-1}) comprising sixteen treatment combinations with three replications. The soil of the experimental site found neutral to alkaline in reaction (pH 7.13), non-saline (0.21 dS m^{-1}) in nature, medium in organic carbon (5.13 g kg^{-1}), low in available nitrogen (224 kg N ha^{-1}), medium in phosphorus (13.26 kg P2O5 ha^{-1}), high in available potassium (345.19 kg K2O ha^{-1}), medium available Sulphur (21.35 kg S ha^{-1}) and clayey in texture. Applied nitrogen and Sulphur levels highest plant height (83.85 & 79.91 cm), number of branches $plant^{-1}$ (27.70 & 21.88), number of capitula $plant^{-1}$ (18.62 & 17.71), number of seed $capitula^{-1}$ (21.20 & 20.71), Test weight (51.23 & 51.16 g), seed yield (17.89 & 16.73qha^{-1}) stover yield (52.21 & 47.66 q ha^{-1}), were recorded with 135 kg N ha^{-1} & 45 kg S ha^{-1} and lowest was found under control.

Keywords: Safflower, nitrogen and Sulphur, growth, yield

Introduction
Nitrogen is an essential plant nutrient being a component of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes, hormones and promotes rapid plant growth and improves yield attributes through maximum tillering, leaf area, seed formation and protein synthesis etc. and ultimately increases total biomass production, grain yield and its components. Fertilizer nitrogen (N) is believed to have contributed 40% of the growth in per capita food output over the last 50 years (Smile, 2002) [14]. 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) [1]. 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) [2].

Oil seeds are of great value in nutritional demands of mankind, animal feeding, and medicine. Among them, safflower (*Carthamus tinctorius* L.) is an important annual industrial crop. Nitrogen and sulphur nutrition assumes exceeding importance in comparison to other nutrients as both are important components of proteins and adequate supply of both nutrients are essential for potential yield of crops. India is a major safflower growing country and contributes 60 per cent of the total world production and ranks first in area and production is grown in an area of 45.89 thousand hectare with a production of 24.64 lakh tonnes and productivity of 537 kg ha^{-1}. It is cultivated as a source of oil and protein. It contains 34% oil and 22-24% protein and its seeds are rich source of natural antioxidant (Tocopherol). In Chhattisgarh, production of safflower crop was 0.11 thousand tons covering an area of 0.27 thousand hectare having average productivity of 405 kg ha^{-1} (GOI, 2018) [3] and mostly grown in rice-based cropping system as broadcasting or line sown in partially irrigated situations.

Nutrient management is one of the critical inputs in achieving high yield and quality of safflower in which nitrogen and sulphur fertilizers are important inputs with suitable form and doses. N availability is an important factor in determining crop productivity, managing fertilizer rate can be a suitable strategy to improve crop growth and yield when crops need to enhance nutrient uptake. Sulphur is master nutrient of oil seed production, it is essential for protein production because, it is constituent of three main amino acid *viz*., cysteine, and methionine. N and S nutrition interact at many levels as the uptake and assimilation of NO3- and SO42-have much in common, and there are many common products of N and S metabolism (Pilbeam and Barker, 2015) [4].

The available sulphur content of majority of soils of in the country is already low because of low organic matter build up and increase loss of sulphur through leaching and erosion. The oil seed crop requires more quantity sulphur than cereals. Therefore, nitrogen and sulphur application in suitable quantities through appropriate sources may be the important factors for maximizing safflower crop yield in the state.

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). In general nutrients requirement and average removal by safflower crop are reported 3.96 kg N, 0.92 kg P &, 6.32 kg K q^{-1} and 20-30 kg N, 5.16-6.45 kg P, 12.45-16.60 kg K and 10-15 kg S $acre^{-1}$ respectively (GOI, 2014 and AICRP-STCR, 2019-20) [5]. The use efficiency of applied S is reported normally ranged from 8-12 percent in different crops.

Materials and Methods

The experiment was carried out during Rabi season of 2019-20 & 2020-21 at Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya which is located at $21^0$23'N latitude, $81^0$70' E longitude and 296 m altitude above the mean sea level. This area is situated on NH 6 Zora, Raipur (Chhattisgarh) and carried out with 16 treatments and 3 replications were carried out along with four levels of Nitrogen (0,45, 90 & 135) kg/ha and four levels of Sulphur (0, 15,30, 45) kg/ha with the treatment combination of Sowen in Tables 1 the seeds were sown with the recommended practices. And seed rate was 20-25 kg/ha, and the basal application of fertilizers was done and seeds were sown in various plots and all the fertilizers were applied at the basal dose (0:40:30) NPK kg/ha and plot size was 3.5x5.0 m, the plants are spaced at 45x15 cm followed by line sowing.

Table 1: Treatment details

S.N.	Treatment levels	Treatment combination	
	Nitrogen (kgha^{-1})		
I	N1-0	N0S0(Control)	N45S0
II	N2-45	N0S15	N45S15
III	N3-90	N0S30	N45S30
IV	N4-135	N0S45	N45S45
Sulphur (kg ha^{-1})			
I	S1-0	N90S0	N135S0
II	S2-15	N90S15	N135S15
III	S3-30	N90S30	N135S30
IV	S4-45	N^{90}S45	N135S45

Results and Discussion

Yield and yield attributing Character of safflower

Plant height of safflower crop differed significantly with applied nitrogen and levels over control, shown in table 2. The mean plant height with application of nitrogen and sulphur varied from 63.46 to 83.16 & 67.89 to 79.43 cm in the year 2019-20 and 64.61 to 84.3 and 69.29 to 80.39 cm in 2020-21 respectively. The mean highest plant height (83.85 & 79.91) was observed with 135 kg N ha^{-1} & 45 kg S ha^{-1} and the lowest with control As nitrogen as an integral part of photosynthetic activity and its effect on cell elongation resulted in better plant height. Effect of sulphur in plant metabolism of protein and carbohydrate by activating a number of enzymes involved in different reactions of photosynthesis enhancing the plant height. Similar findings were also reported by Singh *et al.* (2000) [8] and Nathan *et al.* (2017) [7]. Number of branches per plant of safflower crop influenced significantly with applied nitrogen levels over control, shown in table 2. The mean number of branches $plant^{-1}$ varied with applied nitrogen and sulphur from 13.83 to 22.0 & 16.42 to 21.0 in the year 2019-20 and 15.66 to 23.41 & 18.08 to 22.75 in 2020-21 respectively. Application of 135 kg N ha^{-1} & 45 kg S ha^{-1} recorded significantly higher mean number of branches $plant^{-1}$ as 22.70 & 21.88. The lowest number of branches $plant^{-1}$ was observed under control. Nitrogen and sulphur role directs in structural and functional in growth of plant improved number of branches with adequate supply of N. These results are in agreement with findings of Fattahi *et al.* (2018) [10] found adequate application of nitrogen directly involved in cell multiplication and plant growth and similar findings of Singh and Singh (2013) [9]. The number of capitula $plant^{-1}$ of safflower differed significantly due to different levels of nitrogen and sulphur over control, shown in table 2. The number of capitula $plant^{-1}$ with applied nitrogen and sulphur ranged from 11.92 to 17.66 & 13.17 to 16.92 in the year 2019-20 and 13.25 to 19.58 & 14.75 to 18.50 in 2020-21 respectively. Application of 135 kg N ha^{-1} & 45 kg S recorded significantly mean higher number of capitula $plant^{-1}$ as 18.62 & 17.71. The lowest number of capitula $plant^{-1}$ was observed under control Application of adequate nitrogen and sulphur produced more number of capitula $plant^{-1}$ which might be due to bētter availability of nitrogen and N containing compounds such as protein, nucleic acid, chlorophyll, and functional enzymes related to the growth and yield attributes, Nathan *et al.* (2017) [7] and Divya (2019) [11]. Number of seeds $capitula^{-1}$ of safflower crop influenced significantly with applied nitrogen and sulphur levels over control, shown in table 2 The mean number of seeds $capitula^{-1}$ with applied nitrogen and varied from 13.0 to 20.58 & 14.25 to 20.25 in the year 2019-20 and 13.5 to 21.66 & 14.92 to 20.17 in 2020-21 respectively. Application of 135 kg N ha^{-1} & 45 kg S ha^{-1} recorded significantly higher mean number of seeds $capitula^{-1}$ as 21.20 & 20.71. The lowest number of seeds $capitula^{-1}$ was observed under control. The higher number of seeds $capitula^{-1}$ might be due to applied nitrogen and sulphur improved plant vigour coupled with increased production and translocation of photosynthates and hence more number of seeds $capitulum^{-1}$, Nathan *et al.* (2017) [7]. Test weight (g) of safflower crop influenced significantly with applied nitrogen levels over control, shown in table 2 The mean test weight with applied nitrogen and sulphr levels ranged from 50.0 to 50.91 & 49.89 to 50.85 in the year 2019-20 and 50.49 to 51.55 & 50.08 to 51.48 in 2020-21 respectively. Application of 135 kg N ha^{-1} & 45 kg S ha^{-1} recorded significantly higher test weight (51.23 g per 1000 seeds). The lowest test weight was observed under control. This was may be due to adequate application of nitrogen and sulphur as directly involved in cell multiplication and effective absorption of applied nutrients from source to sink, Rajesh and Amitesh (2013) [12]. Seed yield of safflower crop influenced significantly with applied nitrogen levels over control, shown in table 2. The mean seed yield with applied nitrogen and sulphur ranged from 10.66 to 16.84 & 12.29 to 15.74 in the year 2019-20 and 12.87 to 18.95 & 14.56 to 17.72 in 2020-21 respectively. Application of nitrogen & sulphur @ 135 kg ha^{-1} & 45 kg ha^{-1} recorded significantly higher mean seed yields as 17.89 & 16.73 q ha^{-1}. The lowest seed yields was observed under control On the basis of mean

data, the per cent increase in seed yield with applied @ 135,90 and 45 kg N ha^{-1} were as 52.13, 48.21 and 16.84% and applied S @ 15, 30 and 45 kg S ha^{-1} was 8.12, 20.56 and 24.66% compared to the control, respectively. Maximum nutrient availability due to integrated use of N and S fertilizers increased nutrient uptake by the plant which in turn lead to safflower seed yield. Patil *et al*. (2018) [13]. These findings are inconformity with the results of Singh and Singh (2013) [9], and Nathan *et al.* (2017) [7]. Stover yield of safflower crop influenced significantly with applied nitrogen and sulphur levels over control, shown in table 2. The mean stover yield with applied nitrogen and sulphur ranged from 30.92 to 49.91 & 35.48 to 46.44 in the year 2019-20 and 33.18 to 52.51 & 38.0 to 48.88 in 2020-21 respectively. The stover yield of safflower differed significantly due to different levels of nitrogen and sulphur levels. Application of 135 kg N ha^{-1} and 45 kg S ha^{-1} was recorded significantly higher mean stover yields as 51.21 & 47.66 q ha^{-1}. On the basis of mean data, the percent increase in stover yield with 135, 90 and 45 kg N ha^{-1} was 59.78, 55.23 and 19.81% and 15, 30 and 45 kg S ha^{-1} was 11.46, 25.42 and 29.72% compared to the control, respectively. These findings are in conformity with the results of Singh and Singh (2013) [9], and Nathan *et al.* (2017) [7].

Table 2: Effect of nitrogen and Sulphur levels on yield and yield attributing parameters of safflower

Nitrogen levels (kg ha^{-1})	Plant height (cm)	Number of branches^{-1}	Number of capitula plant-1	Number of seeds capitula-1	Test weight (g)	Seed yield (q ha-1)	Yield Increase (%) over control	Stover yield(qha-1)	Yield increase (%) over control
N_0	64.0	14.75	12.58	13.08	50.24	11.76	-	32.05	-
N_{45}	70.34	20.0	15.12	18.12	50.58	13.74	16.8	38.40	19.8
N_{90}	81.70	20.45	18.12	20.5	50.99	17.43	48.2	49.75	55.2
N135	83.85	20.07	18.62	21.20	51.23	17.89	52.1	51.21	59.7
S.Em ±	0.65	0.56	0.27	0.38	0.14	0.19		0.74	
CD (p=0.05)	1.89	1.61	0.77	1.08	0.39	0.53		2.13	
Sulphur levels (kgha^{-1})									
S_0	68.59	17.25	13.96	14.58	49.99	13.42	-	36.74c	-
S_{15}	72.98	19.79	15.83	17.71	50.89	14.51	8.12	40.95	11.4
S_{30}	78.45	21.00	16.96	19.92	51.02	16.18	20.5	46.08	25.4
S_{45}	79.91	21.88	17.71	20.71	51.16	16.73	24.6	47.66	29.7
S.Em ±	0.65	0.56	0.27	0.38	0.14	0.19		0.74	
CD (p=0.05)	1.89	1.61	0.77	1.08	0.39	0.53		2.13	

Conclusion

The highest yield and yield attributing parameters such as plant height (83.85 & 79.91cm), number of branches plant^{-1} (27.70 & 21.88), number of capitula plant^{-1} (18.62 & 17.71), number of seed capitula^{-1} (21.20 & 20.71), Test weight (51.23 & 51.16g), seed yield (17.89 & 16.73 q ha^{-1}) stover yield (52.21 & 47.66 qha^{-1}), were recorded with 135 kg N ha^{-1} & 45 kg S ha^{-1} and lowest was found under control.

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