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Effect of sulphur and phosphorus levels on growth attributes and economics of safflower (*Carthamus tinctorius* L.)

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Abstract
The field experiment was entitled "Effect of Sulphur and Phosphorus levels on Growth attributes and Economics of Safflower (*Carthamus tinctorius* L.) var. "ISF-764" was conducted during Rabi 2020 at (CRF) Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P.). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (Ph 7.5), low in organic carbon (0.50%), available nitrogen (228.59 kg/ha), available phosphorus (29.80 kg/ha) and available potassium (125.21 kg/ha). The experiment was laid out in randomized block design with nine treatments consists of *viz*., T_1: 20kg/ha Sulphur + 30kg/ha Phosphorus, T_2: 20kg/ha Sulphur + 40kg/ha Phosphorus, T_3: 20kg/ha Sulphur + 50kg/ha Phosphorus, T_4: 30kg/ha Sulphur + 30kg/ha Phosphorus, T_5: 30kg/ha Sulphur + 40kg/ha Phosphorus, T_6: 30kg/ha Sulphur + 50kg/ha Phosphorus, T_7: 40kg/ha Sulphur + 30kg/ha Phosphorus, T_8: 40kg/ha Sulphur + 40kg/ha Phosphorus, T_9: 40kg/ha Sulphur + 50kg/ha Phosphorus and were replicated thrice. Results obtained that there was Singificantly highest in Growth attributes *viz*., Plant height (105.66 cm), Number of Branches/plant (23.53), Dry weight (41.12 g), Crop growth rate (3.53 g/m^2/day), Relative growth rate (0.01 g/g/day) were recorded superior with the application of 40 kg/ha Sulphur + 50 kg/ha Phosphorus. In Economics the highest Gross returns (84080.00 INR/ha), Net returns (60720.00 INR/ha) and B:C ratio (2.59). Therefore, application of 40 kg/ha Sulphur + 50 kg/ha Phosphorus was more productive and economically feasible.

Keywords: Economics, growth attributes, Safflower, Sulphur (S) and Phosphorus (P)

Introduction
India is the largest producer of oil seeds in the world and oil seed sector occupies an important positions in the countries economy. The country accounts for 12-15% global oil seeds area, 6-7% of vegetable oil productions and 9-10% of the total edible oil consumption. In terms of acreage, production and economic value, oil seed are second only to food grains. Safflower is an important oil seed crop of the world. In India, it is grown in winter season and accounts for about 8% of the value of total oil seeds produce. Safflower has a deep root system and thus, can capture leched nutrients below the rooting zone of other crops. 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 outing time. Late sown safflower is exposed to high temperature during the reproductive face, 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.
Safflower is broadleaf oi; seed crop of the family Asteraceae, predominantly adapted to dryland. It originated in southern Asia and it is cultivated in China, India, Persia, Egypt and Pakistan. In the world it was cultivated over an area 0.964 million hectare and had a production of 0.651 million tones with average productivity of 827.9 kg/ha Anonymus (2014) [1]. India is a major safflower growing country and contributes 60 percent of the total world production. India ranks first in area and production of safflower grown across the world. In India, safflower is grown in an area of 1,78,400 ha with a production of 1.453 lakh tonnes and productivity of 498 kg/ha Kumar (2000) [12]. Sulphur is considered as quality nutrient as its application not only influences crop yield but also improves crop quality owing to its influence on protein metabolism, oil synthesis and formation of amino acids. It is a constituent of 3 amino acids *viz*., Methionine (21% S), Cysteine (26% S) and cystine (27% S), which are building blocks of proteins.

Sulphur use was also reported to bevery remunerative in many crops sequences involving oil seeds. Sulphur application in suitable quantities throw appropriate source may be the corrective measure to improve the safflower yield. Erdal *et al*., (2006) [7] reported that soil pH decreased with the application of S, resulting in increase in nutrient concentration, plant nutrient uptake, chlorophyll concentration, root nodules and dry matter production. Hence, an attempt was made to study the effect of Sulphur levels and sources on growth, yield and nutrient uptake parameters of Safflower (*Carthamus tinctorius* L.). Oil seeds are energy rich crops, so Phosphorus and Sulphur nutrients assumes greater importance in comparison to other nutrients. This application of these elements as they have becoming limiting factor for obtaining higher yields of several oil seed crops including Safflower.

Phosphorus plays an important role in the plant growth and development, is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient moment with in the plant and tranfer of genetic characteristics from one generation to the next generation Sultenfuss and Doyle (1999) [25]. An adequate supply of phosphorus in the early stages helps in initiating its reproductive parts. The better development of yield attributes with Phosphorus fertilization might be due to its key rele in root development, energy translocation and metabolic processes of plant through which increased translocation of photosynthesis towards sink development might have occurred. The results of this work is expected to evaluate the effect of phosphorus levels on growth and yield components of safflower and to determined the optimum level of Phosphorus to be applied so as to determined suitable recommendation in this area. It is the most limiting nutrient for crop growth and yield in many regions of the world and application of P fertilizer represents an important measure to correct nutrient deficiencies and to replace nutrients having been removed in the products harvested Dambroth and El-Bassam (1990) [10].

Materials and Methods

The field experiment was entitled "Effect of Sulphur and Phosphorus levels on yield, yield attributes and quality parameters of Safflower (*Carthamus tinctorius* L.) var. "ISF-764" was conducted during Rabi 2020 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P.). the CRF is situated at 25 ^{0} 24'41.27' N latitude, 81^{0} 50'56' E longitude and 98 m altitude above the mean sea level (MSL). This area is situated on the right side of the Yamuna River by the side of Prayagraj – Rewa road about 12 km from the city. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (Ph 7.5), low in organic carbon (0.50%), available nitrogen (228.59 kg/ha), available phosphorus (29.80 kg/ha) and available potassium (125.21 kg/ha). The experiment was laid out in randomized block design. The 2 factors Sulphur and Phosphorus has three levels i.e., Sulphur @ 20,30,40 kg/ha and Phosphorus @ 30,40,50 kg/ha respectively comprising of 9 treatment with the combination of T_1: 20kg/ha Sulphur + 30kg/ha Phosphorus, T_2: 20kg/ha Sulphur + 40kg/ha Phosphorus, T_3: 20kg/ha Sulphur + 50kg/ha Phosphorus, T_4: 30kg/ha Sulphur + 30kg/ha Phosphorus, T_5: 30kg/ha Sulphur + 40kg/ha Phosphorus, T_6: 30kg/ha Sulphur + 50kg/ha Phosphorus, T_7: 40kg/ha Sulphur + 30kg/ha Phosphorus, T_8: 40kg/ha Sulphur + 40kg/ha Phosphorus, T_9: 40kg/ha Sulphur + 50kg/ha Phosphorus and reach were replicated thrice. Treatments were randomly arranged in each replication, divided into 27 plots. The recommended dose of 40:40:20 N:P:K were applied according to treatment details. Five random plant samples were collected from each plot at the time of harvest for recording observations on plant yield attributes. In the period from germination to harvest several growth parameters were recorded at frequent intervals long with it after harvest several yeald parameters were recorded those growth parameters *viz*., plant height, no of branches per plant, plant dry matter accumulation, crop growth rate and relative growth rate were recorded. Experimental data collected was subjected to statistical analysis by adopting fishers method of analysis of variance (ANOVA) as outline by Gomez, K.A. and Gomez, A.A (1984). Critical difference (CD) value were calculated whenever the 'F' test was found significant at 5% level.

Results and Discussion

Plant Height

Growth attributes in Table.1 revealed that Safflower crop fertilized with the application of 40 kg/ha Sulphur + 50 kg/ha Phosphorus significantly resulted maximum plant height (39.52 cm, 70.13 cm, 85.66 cm and 105.66cm) at 60 DAS, 80 DAS, 100 DAS and At harvest.

However, at 60 DAS 30 kg/ha Sulphur + 30 kg/ha Phosphorus (38.21 cm), 30 kg/ha Sulphur + 50 kg/ha Phosphorus (38.99 cm), 40 kg/ha Sulphur + 30 kg/ha Phosphorus (37.52 cm) and 40 kg/ha Sulphur + 40 kg/ha Phosphorus (39.48 cm) were statistically at par with treatment no.9 (40 kg/ha Sulphur + 50 kg/ha Phosphorus).

However, at 80 DAS 30 kg/ha Sulphur + 50 kg/ha Phosphorus (67.05 cm), 40 kg/ha Sulphur + 40 kg/ha Phosphorus (67.55 cm) were statistically at par with treatment no.9 (40 kg/ha Sulphur + 50 kg/ha Phosphorus).

However, at 100 DAS 30 kg/ha Sulphur + 50 kg/ha Phosphorus (84.01 cm), 40 kg/ha Sulphur + 30 kg/ha Phosphorus (83.51 cm) and 40 kg/ha Sulphur + 40 kg/ha Phosphorus (84.39 cm) were statistically at par with treatment no.9 (40 kg/ha Sulphur + 50 kg/ha Phosphorus).

However, at Harvest 20 kg/ha Sulphur + 40 kg/ha Phosphorus (102.17 cm), 30 kg/ha Sulphur + 50 kg/ha Phosphorus (103.23 cm), 40 kg/ha Sulphur + 30 kg/ha Phosphorus (102.42 cm) and 40 kg/ha Sulphur + 40 kg/ha Phosphorus (104.28 cm) were statistically at par with the treatment no.9 (40 kg/ha Sulphur + 50 kg/ha Phosphorus).

The probability of increase in plant height by the application of higher levels of Sulphur would have been due to multiple roles of Sulphur in carbohydrate metabolism of plants by activating several enzymes which participant in dark reaction of photosynthesis hence increasing the plant height. Ravi *et al*. (2008) [17]. Similarly, Phosphorus plays a vital role in photo-synthesis, respiration, energy storage and transfer, cell division, cell enlargement and development of meristematic tissues which helps in increase plant height. Similar findings were reported by Sofy *et al.,* (2020) [22] and Mengal and Kirkby (2000) [14].

No. of Branches / plant

Growth attributes in Table.1 revealed that Safflower crop fertilized with 40 kg/ha Sulphur + 50 kg/ha Phosphorus significantly resulted highest Number of Branches per Plant (4.87, 12.27, 17.63 and 23.53) at 60 DAS, 80 DAS, 100 DAS and At harvest. However, at 60 & 80 DAS 40 kg/ha Sulphur + 40 kg/ha Phosphorus (4.20, 10.87) were statistically at par with treatment no.9 (40 kg/ha Sulphur + 50 kg/ha Phosphorus).However, at 100 DAS 30 kg/ha Sulphur + 50 kg/ha Phosphorus (17.03), 40 kg/ha Sulphur + 30 kg/ha Phosphorus (16.95) and 40 kg/ha Sulphur + 40 kg/ha Phosphorus (17.20). However, at harvest 20 kg/ha Sulphur + 50 kg/ha Phosphorus (20.90), 30 kg/ha Sulphur + 40 kg/ha Phosphorus (20.93), 30 kg/ha Sulphur + 50 kg/ha Phosphorus (22.47) and 40 kg/ha Sulphur + 40 kg/ha Phosphorus (23.13) were statistically at par with treatment no.9 (40 kg/ha Sulphur + 50 kg/ha Phosphorus).The increase in Number of Branches per plant can be due to favourable effects of sulphur (S) and phosphorus (P) increasing the chlorophyll synthesis and metabolic activity, cel division and exportation which ultimately enchanced the growth in terms of No. of Branches, these results were in revealed by Ravi *et al.* (2010) [17] and Baviskar *et al.* (2005) [3].

Table 1: Effect of Sulphur and Phosphorus levels on plant height and number of Branches/plant at 60, 80, 100 DAS and at harvest of Safflower.

S. No.	Treatments	Plant Height (cm)				Number of Branches/plant			
		60 DAS	80 DAS	100 DAS	At harvest	60 DAS	80 DAS	100 DAS	At harvest
1.	Sulphur 20 kg/ha+ Phosphorus 30 kg/ha	33.07	57.80	76.47	96.78	2.73	9.13	11.36	18.57
2.	Sulphur 20 kg/ha+ Phosphorus 40 kg/ha	36.57	65.07	81.07	102.17	3.40	10.07	16.73	20.53
3.	Sulphur 20 kg/ha+ Phosphorus 50 kg/ha	35.69	63.06	82.40	99.17	3.13	10.13	15.89	20.90
4.	Sulphur 30 kg/ha+ Phosphorus 30 kg/ha	38.21	65.01	83.18	100.10	2.73	9.20	14.03	19.47
5.	Sulphur 30 kg/ha+ Phosphorus 40 kg/ha	36.90	62.91	80.47	99.83	3.47	10.00	16.67	20.93
6.	Sulphur 30 kg/ha+ Phosphorus 50 kg/ha	38.99	67.05	84.01	103.23	3.87	10.43	17.03	22.47
7.	Sulphur 40 kg/ha+ Phosphorus 30 kg/ha	37.52	63.93	83.51	102.42	2.53	9.67	16.95	19.80
8.	Sulphur 40 kg/ha+ Phosphorus 40 kg/ha	39.48	67.55	84.39	104.28	4.20	10.87	17.20	23.13
9.	Sulphur 40 kg/ha+ Phosphorus 50 kg/ha	39.52	70.13	85.66	105.66	4.87	12.27	17.63	23.53
	F- test	S	S	S	S	S	S	S	S
	S.Em	0.69	1.64	0.82	1.48	0.26	0.49	0.28	0.97
	CD(5%)	2.06	4.92	2.47	4.45	0.77	1.46	0.84	2.90

Dry weight (g) Production

The analysed data presented in (Table.2) shown significantly highest dry weight was recorded with the application of 40 kg/ha Sulphur + 50 kg/ha Phosphorus (16.24 g, 26.34 g, 35.3 g and 41.12 g) at 60 DAS, 80 DAS, 100 DAS and At harvest. However at 60 DAS, 80 DAS and 100 DAS 30 kg/ha Sulphur + 50 kg/ha Phosphorus (14.92 g, 24.93 g and 33.97 g) and 40 kg/ha Sulphur + 40 kg/ha Phosphorus (15.32 g, 25.12 g and 34.17g). However at harvest 40 kg/ha Sulphur + 40 kg/ha Phosphorus (40.46 g) which were statistically at par with 40 Kg/ha Sulphur + 50 kg/ha Phosphorus. The increase in dry mry matter production due to favourable effects of sulphur and phosphorus in stimulated the photosynthetic activity and synthesis of chloroplast protein which might have resulted in higher dry matter production by Harendra Kumar and Yadav, (2007) [9].

Table 2: Effect of Sulphur and Phosphorus Levels on Dry weight (g) Production, Crop growth rate and Relative growth rate of Safflower (*Carthamus tinctorius* L.).

S. No.	Treatments	Dry weight production (g)				Crop growth rate ($g/m^2/day$)				Relative growth rate (g/g/day)			
		60 DAS	80 DAS	100 DAS	At harvest	40-60 DAS	60-80 DAS	80-100 DAS	100 das-At harvest	40-60 DAS	60-80 DAS	80-100 DAS	100 das-At harvest
1.	Sulphur 20 kg/ha+ Phosphorus 30 kg/ha	12.32	20.44	30.44	35.04	5.38	9.18	5.56	2.56	0.08	0.03	0.02	0.01
2.	Sulphur 20 kg/ha+ Phosphorus 40 kg/ha	13.19	22.47	31.54	36.57	5.80	10.26	5.01	2.83	0.08	0.03	0.02	0.01
3.	Sulphur 20 kg/ha+ Phosphorus 50 kg/ha	13.87	23.39	32.42	38.26	6.05	9.95	5.04	3.26	0.08	0.03	0.02	0.01
4.	Sulphur 30 kg/ha+ Phosphorus 30 kg/ha	13.62	22.87	31.92	37.78	5.99	10.25	4.97	3.28	0.08	0.03	0.02	0.01
5.	Sulphur 30 kg/ha+ Phosphorus 40 kg/ha	14.46	23.66	32.69	38.67	6.17	10.34	5.12	3.34	0.07	0.02	0.01	0.01
6.	Sulphur 30 kg/ha+ Phosphorus 50 kg/ha	14.92	24.93	33.97	39.91	6.17	11.42	4.98	3.32	0.07	0.03	0.02	0.01
7.	Sulphur 40 kg/ha+ Phosphorus 30 kg/ha	14.10	24.53	33.58	39.47	6.10	12.02	5.08	3.30	0.08	0.03	0.02	0.01
8.	Sulphur 40 kg/ha+ Phosphorus 40 kg/ha	15.32	25.12	34.17	40.46	6.39	10.71	5.06	3.53	0.07	0.03	0.02	0.01
9.	Sulphur 40 kg/ha+ Phosphorus 50 kg/ha	16.24	26.34	35.33	41.12	6.76	12.00	4.99	3.22	0.07	0.02	0.01	0.01
	F- test	S	S	S	S	S	NS	NS	NS	S	NS	NS	NS
	SEM	0.45	0.48	0.51	0.27	0.22	0.86	0.47	0.20	0.00	0.00	0.00	0.00
	CD(5%)	1.34	1.44	1.52	0.81	0.66	-	-	-	0.00	-	-	-

Crop growth rate ($g/day/m^2$)

The analysed data presented in Table No.3 shown significant variation among all other treatments. At 40-60 DAS significantly maximum Crop growth rate in treatment no.9 with the application of Sulphur 40 kg/ha + Phosphorus 50 kg/ha (6.76 $g/day/m^2$). However, (6.10 $g/day/m^2$) with the application of Sulphur 30 kg/ha + Phosphorus 40 kg/ha, (6.17 $g/day/m^2$) with the application of Sulphur 30 kg/ha + Phosphorus 40 kg/ha and Sulphur 30 kg/ha + Phosphorus 50 kg/ha and (6.39 $g/day/m^2$) with the application of Sulphur 40 kg/ha + Phosphorus 40 kg/ha were recorded statistically at par with treatment no.9 with the combination of 40 kg/ha Sulphur + 50 kg/ha Phosphorus.

Maximum crop growth rate at 60-80 DAS, 80-100 ADS and 100 DAS- at harvest was recorded with the application of Sulphur 40 kg/ha + Phosphorus 50 kg/ha (12.00 $g/day/m^2$, 4.99 $g/day/m^2$ and 3.22 $g/day/m^2$) and Sulphur 20 kg/ha + Phosphorus 40 kg/ha (9.18 $g/day/m^2$, 4.97 $g/day/m^2$ and 2.56 $g/day/m^2$) while the effect of treatments were found to be non-significant. Different levels of sulphur was positively influences on accumulations of plants dry weight which has cumulative effect on accumulations of photosynthates leads to positive impact on crop growth.

Table 3: Effect of Sulphur and Phosphorus levels on Economics of Safflower (*Carthamus tinctorius* L.).

Treatment. No.	Treatment combinations	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
T_1	20 kg/ha Sulphur + 30 kg/ha Phosphorus	21260	50469.60	29209.60	1.37
T_2	20 kg/ha Sulphur + 40 kg/ha Phosphorus	21410	66319.60	44909.60	2.09
T_3	20 kg/ha Sulphur + 50 kg/ha Phosphorus	20560	61093.60	40533.60	1.97
T_4	30 kg/ha Sulphur + 30 kg/ha Phosphorus	22160	71686.00	49526.00	2.23
T_5	30 kg/ha Sulphur + 40 kg/ha Phosphorus	22310	66221.20	43911.20	1.96
T_6	30 kg/ha Sulphur + 50 kg/ha Phosphorus	22460	77076.80	54616.80	2.43
T_7	40 kg/ha Sulphur + 30 kg/ha Phosphorus	23060	67694.40	44634.40	1.93
T_8	40 kg/ha Sulphur+ 40 kg/ha Phosphorus	23210	80027.60	56817.60	2.44
T_9	40 kg/ha Sulphur + 50 kg/ha Phosphorus	23360	84080.00	60720.00	2.59

Relative growth rate (g/g/day)

The data related to relative growth rate was presented in Table 2. Maximum relative growth rate (g/g/day) at 40-60 DAS, 60-80 DAS, 80-100 ADS and 100 DAS-at harvest was recorded with the application of Sulphur 40 kg/ha + Phosphorus 50 kg/ha (0.08 g/g/day, 0.03 g/g/day, 0.02 g/g/day and 0.01 g/g/day) and Sulphur 20 kg/ha + Phosphorus 40 kg/ha (0.04 g/g/day, 0.07 g/g/day, 0.02 g/g/day and 0.01 g/g/day) while the effect of treatments were found to be non-significant.

Economics

The data in Table.3 represents The highest gross returns (84080.00 INR/ha), net returns (60720.00 INR/ha) and B:C ratio (2.59) were recorded in treatment no.9 with the application of Sulphur 40 kg/ha + Phosphorus 50 kg/ha.

Conclusion

From the above experiment it is concluded that sowing of Safflower with the application of Sulphur 40 kg/ha along with Phosphorus 50 kg/ha has been found to be more productive and remunerative. These findings are based on one season therefore, further trails may be required for considering it as recommendation.

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