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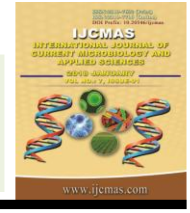

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Effect of Potassium and Sulphur on Nutrient Uptake, Yield and Quality of Safflower in Vertisol

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A B S T R A C T

The field experiment was conducted to study the "Effect of potassium and sulphur on nutrient uptake, yield and quality of safflower in Vertisol at Collage of Agriculture Farm, Nagpur during *rabi* season of 2014-2015. Twelve treatment combinations were studies in FRBD with three replication, which comprises four levels of potassium (0, 10, 20 and 30 kg ha^{-1}) and three levels of sulphur (10, 20 and 30 kg ha^{-1}). The significant increase in seed and straw yield of safflower (15.02 and 36.06 q ha^{-1}, respectively) were recorded due to application of potassium at 30 kg ha^{-1}, whereas, significantly higher seed and straw yield of safflower (14.65 and 35.16 q ha^{-1}, respectively) were recorded due to application of sulphur at 30 kg ha^{-1}. The content and uptake of N, P, K and S improved in seed and straw of safflower significantly due to application of potassium up to 20 kg potassium ha^{-1} and sulphur up to 20 kg sulphur ha^{-1}. The improvement in fertility status in soil for major nutrients and also quality of seed in safflower was influenced due to the application of potassium and sulphur levels.

Introduction

Safflower (*Carthamus tinctorius* L.) is an important edible rabi oilseed crop of India, widely grown on large scale. Low cost of production and high yield potentials hold promise for its large scale cultivation in the country (Chiddha Singh, 1998).

The seed contains 24-36% oil and the protein content of the whole seed ranges from 11-24%. High oleic oil is a beneficial agent in the prevention of coronary artery disease (Dajue and Mundel, 1996). In the world it was cultivated over an Area 0.964 million hectare, and had a production of 0.651 million tonnes with average productivity of 827.9 kg ha^{-1} (Anonymous, 2014). India is the largest producer of safflower in the world, By making the 29.2% of world's safflower production, India is placed on the top (Ekin, 2005).

Saalbach (1973) reported that, sulphur deficiency tends affect adversely the growth and yield of seed crop, which reduces the crop yield to an extent of 10-30%.for oilseed, potassium and sulphur are most vital nutrient for the growth and development of safflower crop. Besides N and P, the use of K has been reported to influence the productivity of seed yield and seed oil content (Ghosh *et al.*, 1995)

Kau and Chen (1980) reported that K increase the seed oil content of towar var. of rapeseed. Kandalp and Chandel (1993) also reported that application of K improved of rapeseed. Sulphur is master nutrient of oil seed production, it is essential for protein production because, it is constituent of three main amino acid viz., cystine, cysteine, methionine. 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 SO_4sulphur through leaching and erosion. The oil seed crop require more quantity sulphur than cereals.so deficiency of sulphur occurs in the soils (Singh and Sahu, 1986).

Materials and Methods

The field experiment was carried out at experimental field at EAD farm, College of Agriculture, Nagpur. The experiment was laid out in FRBD with sixteen treatment combinations each replication thrice. Treatment combination are (T_1+ T_2 + T_3, K @ 0 kg ha^{-1}+ S @ 10,20,30 kg ha^{-1}, T_4+T_5+T_6 K @ 10 kg ha^{-1} + S @ 10,20,30 kg ha^{-1}, T_7+T_8+T_9 K @ 20 kg ha^{-1}+S @ 10,20,30 kg ha^{-1},T_{10}+T_{11}+T_{12} K @ 30 kg ha^{-1} + S @ 10,20,30 kg ha^{-1}).

Recommended dose of fertilizer 40:40:00 kg NPK ha^{-1} was applied in the form of P-DAP, N-Urea. Three levels of S @ 10, 20, 30 kg $ha^{-1}$and four levels of K @ 0,10,20,30 kg ha^{-1} applied through Bentonite-S, and MOP respectively.

Available potassium in soil was extracted by Neutral normal ammonium acetate solution and potassium was determined using flame photometer (Jackson, 1967), available sulphur was determined by Turbid metric method given by Chesnin and Yien (1951). To carry out chemical analysis of plant, the randomly selected plot wise.

Results and Discussion

Seed and straw yield of safflower

From the data presented in table 2, revealed that the highest seed yield of safflower (15.02 q ha^{-1}) was obtained with application of 30 kg potassium ha^{-1} over all other levels of potassium. The significant increase in seed yield of safflower was recorded up to application of 30 kg potassium ha^{-1} with the increase supply of potassium. Similar results were reported by Abasiyeh *et al.,* (2012) that increasing the levels of potassium there was a significant increased in seed yield of safflower. The response of sulphur to seed yield of safflower was significant with increasing levels of sulphur. The highest seed yield of safflower (14.65 q ha^{-1}) was recorded with the application of 30 kg S ha^{-1}, 10 kg S ha^{-1} (13.23 q ha^{-1}) and which was found to be at par with the application of 20 kg sulphur ha^{-1} (14.46 q ha^{-1}). The results are in conformity with the findings of Tetarwal *et al.,* (2013) that seed and straw yield increased significantly up to 30 kg S ha^{-1}. Piri and Sharma (2006) found that application of 15, 30 and 45 kg S ha^{-1} increase seed yield over control by 9, 15 and 23%, respectively.

Significant influence of sulphur on yield in safflower has also been observed by Dashora and Sharma (2006). Ravi *et al.,* (2008) revealed that the higher seed yield (1553 kg ha^{-1}) was obtained with the higher sulphur levels (30 kg S ha^{-1}). This might be due to more accumulation of amino acids and amide substances and their translocation to reproductive organ, which influenced growth and yield due to sulphur application.

The interaction effect between K and S with respect to seed yield was found statistically significant. The maximum seed yield (15.50 q ha^{-1}) was noticed with $K_{30}S_{30}$ treatment combination which was found to be at par with $K_{20}S_{30}$ (15.08 q ha^{-1}), $K_{20}S_{20}$ (14.96 q ha^{-1}), $K_{30}S_{20}$ (15.38 q ha^{-1}) treatment combinations.

Content (%) and uptake of nitrogen, phosphorus, potassium (kg ha^{-1}) by safflower

The concentration of nitrogen in seed and straw was significantly increased up to 30 kg potassium ha^{-1}. The total uptake on N was significantly increased with increase in potassium levels. The highest total uptake of N (67.52 kg ha^{-1}) was obtained with the application of potassium at 30 kg ha^{-1} which was significantly superior over lower levels of potassium application. The higher concentration of N in seed (3.52%) and straw (0.57%) was observed with the application of 30 kg sulphur ha^{-1}, which was found to be at par with application of 20 kg sulphur ha^{-1} in seed (3.48%) and straw (0.56%). Highest total uptake of N (65.13 kg ha^{-1}) was observed with the application of sulphur @ 30 kg ha^{-1} which was found at par to application of 20 kg sulphur ha^{-1} (63.00 kg ha^{-1}).

The highest content of phosphorus in seed (0.65%) and straw (0.31%) was associated with the treatment 30 kg potassium ha^{-1} followed by application of 20 kg potassium ha^{-1} in seed (0.63%) and straw (0.28%) and lowest content was recorded in control. Total uptake of phosphorus found significantly more (21.08 kg ha^{-1}) with the application of 30 kg potassium ha^{-1}, followed by application of 20 kg potassium ha^{-1} (19.46 kg ha^{-1}) over no application of potassium. The P uptake significantly increased up to 30 kg S ha^{-1}. It is clear from the data that, P content increases up to level of 30 kg sulphur ha^{-1} and was found to be at par with 20 kg S ha^{-1} in seed (0.62 %) and straw (0.30%). The highest total uptake of P (20.23 kg ha^{-1}) was observed with the application of 30 kg sulphur ha^{-1}. Tetarwal *et al.*, (2013) also found that total uptake of phosphorus increased significantly. The highest total uptake of P (23.08 kg ha^{-1}) was observed in $K_{30}S_{30}$ treatment combination which was found to be at par with $K_{20}S_{30}$ (21.53 kg ha^{-1}), $K_{20}S_{20}$ (20.81 kg ha^{-1}) and $K_{30}S_{20}$ (22.71 kg ha^{-1}). The lowest uptake of P (12.23 kg ha^{-1}) was observed in treatment combination (K_0S_{10}).

The application of 30 kg potassium ha^{-1} shows maximum content of K (1.23% in seed and 0.75% in straw) followed by application of 20 kg potassium ha^{-1} (1.18%in seed and 0.74% in straw). The total uptake of K was significantly increased with the increasing levels of potassium (Table 9 and fig. 8). The total uptake of K was found maximum (45.96 kg ha^{-1}) with application of potassium @ 30 kg ha^{-1}, followed by potassium applied at 20 kg ha^{-1}(43.29 kg ha^{-1}). Similar result found by Yadav *et al.,* (2013) revealed that potassium application significantly increased the K content and K uptake in mustard crop which was significantly increased with the increasing levels of potassium. The higher percentage of potassium was recorded in seed (1.19%) and straw (0.76%) with the application of 30 kg sulphur ha^{-1} and was found to be at par with application of 20 kg sulphur ha^{-1} i.e. content of K in seed (1.18%) and straw (0.74%).

The lowest content of K was observed in seed (1.14%) and in straw (0.66%) with the application of 10 kg S ha^{-1}. The total uptake of K was increased significantly with increase in sulphur level. The highest uptake of K (44.63 kg ha^{-1}) was observed with application of 30 kg sulphur ha^{-1}, followed by application of 20 kg sulphur ha^{-1} (42.47 kg ha^{-1}). The maximum total uptake of K (49.58 kg ha^{-1}) was obtained under $K_{30}S_{30}$ treatment combination which was found to be more over K_0S_{10} treatment combination (31.74 kg ha^{-1}). Singh *et al.*, (2013) reported that there was increase in total uptake of N, P, K and S with the application of K and S.

Table.1 Chemical properties at experimental site

Sr.No.	Particulars	Analytical value
1	pH (1:2.5)	7.9
2	EC (dSm^{-1})	0.28
3	Organic carbon %	5.29
4	Avail. N (kg ha^{-1})	174.20
5	Avail. P_2O_5 (kg ha^{-1})	15.53
6	Avail. K_2O (kg ha^{-1})	430.8
7	Avail. Sulphur(mg ha^{-1})	8.23

Table.2 Seed and straw yield (q ha^{-1}) of safflower as influenced by potassium and sulphur levels

Treatments	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
Levels of Potassium (kg ha^{-1})		
K_0	13.13	31.51
K_{10}	13.77	33.05
K_{20}	14.53	34.87
K_{30}	15.02	36.06
'F' test	Sig.	Sig.
SE (m) ±	0.12	0.30
CD at 5%	0.36	0.88
Levels of sulphur (kg ha^{-1})		
S_{10}	13.23	31.75
S_{20}	14.46	34.71
S_{30}	14.65	35.16
'F' test	Sig.	Sig.
SE (m) ±	0.10	0.26
CD at 5%	0.31	0.76
Interaction (Potassium X Sulphur)		
'F' test	Sig.	Sig.
SE (m) ±	0.21	0.52
CD at 5%	0.63	1.52

Table.3 Interaction effects of potassium and sulphur on seed yield (q ha^{-1}) of safflower

Treatments	S_{10}	S_{20}	S_{30}	Mean
K_0	12.38	13.17	13.85	13.13
K_{10}	12.79	14.35	14.18	13.77
K_{20}	13.56	14.96	15.08	14.53
K_{30}	14.20	15.38	15.50	15.02
Mean	13.23	14.46	14.65	
'F' test	Sig.			
SE (m) ±	0.21			
CD at 5%	0.63			

Table.4 Effect of potassium and sulphur on content (%) and uptake of nitrogen, phosphorus, potassium (kg ha^{-1}) by safflower

	Nitrogen content (%)		Total N uptake (kg/ha)	Phosphorus content (%)		Total P uptake (kg/ha)	Potassium Content (%)		Total K uptake (kg/ha)
	Seed	straw	total	Seed	Straw	total	Seed	straw	total
Levels of Potassium (kg ha^{-1})									
K_0	2.53	0.48	54.29	0.53	0.24	14.76	1.10	0.66	35.82
K_{10}	3.14	0.49	58.32	0.61	0.26	17.65	1.15	0.71	39.95
K_{20}	3.47	0.54	63.89	0.63	0.28	19.46	1.18	0.73	43.29
K_{30}	3.73	0.59	67.52	0.66	0.31	21.08	1.23	0.75	45.96
'F' test	**Sig.**	Sig.	Sig.	**Sig.**	Sig.	Sig.	**Sig.**	Sig.	Sig.
SE (m) ±	0.11	0.01	0.59	0.08	0.10	0.38	0.021	0.007	0.64
CD at 5%	0.33	0.04	1.73	0.24	0.27	1.11	0.061	0.020	1.93
Levels of Sulphur (kg ha^{-1}									
S_{10}	3.10	0.49	54.90	0.56	0.23	14.96	1.14	0.66	36.39
S_{20}	3.48	0.56	63.00	0.62	0.30	19.51	1.18	0.74	42.47
S_{30}	3.52	0.57	65.13	0.63	0.31	20.23	1.19	0.76	44.63
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE (m) ±	0.11	0.01	0.50	0.07	0.08	0.32	0.018	0.007	0.56
CD at 5%	0.33	0.04	1.50	0.22	0.24	0.97	0.054	0.023	1.67
Interaction (Potassium x Sulphur)									
'F' test	N.S.	N.S.	Sig.	N.S.	N.S.	Sig.	N.S.	Sig.	Sig.
SE (m) ±	0.22	0.03	1.02	0.16	0.04	0.65	0.039	0.051	1.11
CD at 5%	-	-	3.01	-	-	1.93	-	0.146	3.30

Table.5 Effect of potassium and sulphur on quality of safflower

Treatments	Content in seed (%)	
	Oil content (%)	Protein content (%)
Levels of Potassium (kg ha^{-1})		
K_0	29.16	18.97
K_{10}	30.23	19.22
K_{20}	30.30	19.48
K_{30}	30.32	19.53
'F' test	Sig.	Sig.
SE (m) ±	0.012	0.32
CD at 5%	0.040	0.96
Levels of Sulphur (kg ha^{-1})		
S_{10}	30.15	19.08
S_{20}	30.29	19.34
S_{30}	30.34	19.48
'F' test	Sig.	Sig.
SE (m) ±	0.012	0.28
CD at 5%	0.040	0.83
Interaction (Potassium x sulphur)		
'F' test	N.S.	N.S.
SE (m) ±	0.031	0.56
CD at 5%	-	-

Quality of safflower

The oil content of safflower seed increased from 29.16% in control to 30.32% at 30 kg potassium ha^{-1}. Application of 30 kg potassium ha^{-1} shows maximum oil content 30.32% followed by 20 kg potassium ha^{-1} (30.30%). It is evident from the data in the table 8 that successive increasing sulphur application from 10 to 30 kg sulphur ha^{-1} significantly increased the oil content in safflower seed. Application of 30 kg sulphur ha^{-1} recorded highest oil content (30.34%) followed by 20 kg sulphur ha^{-1} (30.29%), whereas lowest value of oil content was recorded with the application of 10 kg S ha^{-1}. Oil storage organs of oil seed crops including safflower are mostly protein rich in sulphur and the supply of sulphur to these crops is paramount importance. The results are in agreement with the findings of Tetarwal *et al.*, (2013) reported that the application of 30 kg S ha^{-1}, recorded significantly higher oil content in seed than other treatment in mustard crop. Similar results were reported by Zizala *et al.*, (2008) and Faisal *et al.*, (2013) Chauhan (2013) reported that the seed oil content greatly influenced by various level of potash and sulphur. Protein content varied from 19.08 to 19.48% with increasing levels of sulphur from 10 to 30 kg sulphur ha^{-1} which were increased linearly over the lower level. Singh *et al.*, (2008) reported that oil and protein yields were significantly increased by N and S levels due to increase in seed yields. Similar finding were reported by Panchal *et al.*, (2011) and Zizala *et al.*, (2008).

Ravi *et al.*, (2008) stated that the data on oil content showed significant differences in oil content of safflower seeds due to sulphur application. The treatment receiving 30 kg S ha^{-1} resulted in the maximum oil content (29.1%). This was significantly superior over 20 kg S ha^{-1}(28.3%), 10 kg S ha^{-1} (26.9%) and control (26.35%). This might be due to role of sulphur in synthesis of oil, sulphur is involved in the formation of glucosides and glcosinolates (mustard oil) and sulphydril-linkage and activation of enzyme which aid in the biochemical reaction within the plant. The treatment receiving 30 kg S ha^{-1} recorded the highest protein content (14.63%) and it was significantly superior over 20 kg S ha^{-1}(13.5%), 10 kg S ha^{-1}(12.3%) and control (11.3%).This is might be due to role of sulphur in protein synthesis. Sulphur is a constituent of essential amino acids viz. methionine, cysteine and cystine. These results are in support with the findings of Babhulkar *et al.,* (2000), in safflower and Shekhargouda *et al.*, (1997) in safflower lend support to this study.

The application of potassium up to 20 kg ha^{-1} and sulphur up to 20 kg ha^{-1} significantly influence the seed and straw yield of safflower. The concentration and uptake of N, P, K and S also improved in seed and straw of safflower. Application of potassium and sulphur improves the quality of seed in safflower by increasing oil and protein content. Application of potassium and sulphur help to improve the availability of N, P, K, and S in the soil.

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