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Effect of sulphur on growth, yield and quality of linseed (*Linum usitatissimum* L.) genotypes

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ABSTRACT

A field experiment was carried out during winter seasons of 2017-18 and 2018-19 at the Private Research Farm, Benda-Semaria Road, Rewa (M.P.) to study the effect of sulphur on growth, yield-attributes, yield and quality of linseed genotypes. Five genotypes and four levels of sulphur were evaluated in factorial randomized block design with three replications. Amongst the linseed genotypes, JLS-67 proved the most suitable genotype with respect to growth parameters, yield-attributes, seed yield and its quality as well as monetary gain per hectare of production. Thus, this genotype (JLS-67) gave the maximum seed yield (16.95 q ha^{-1}), seed oil content (43.81%), seed protein content (19.69%) and the net income (Rs.61800 ha^{-1}). Application of fertilizer sulphur upto 60 kg ha^{-1} resulted in maximum growth parameters, yield-attributes, seed yield and its quality as well as monetary gain. The seed yield was upto 15.68 q ha^{-1}, seed oil (44.31%), seed protein (18.37%) and the net income upto Rs.53267 ha^{-1}. Consequently the linseed genotype JLS-67 may be grown applied with 60 kg S ha^{-1} to obtain further enhanced productivity, nutritional quality as well as economical gain under the existing agro-climatic conditions of Kymore plateau of Madhya Pradesh.

Key words: Genotypes, sulphur, growth, yield, quality, linseed

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is an important industrial oilseed and fibre crop of India stands next to rapeseed-mustard in *rabi* oilseeds in area and production. India is the second largest producer of linseed, next to Canada in the world with an area of 5.25 lakh ha, total production of 2.11 lakh tones per annum and productivity of 403 kg ha^{-1}. In India, Madhya Pradesh leads in yield and acreage, followed by Uttar Pradesh. Madhya Pradesh and Uttar Pradesh together contribute to national linseed production to the extent of about 70 per cent. The average productivity of this crop is very low as compared to other oilseed crops which can be attributed to several reasons. The major causes behind low production are cultivation of linseed mainly in marginal and sub-marginal lands. The continuous use of S-free high analysis N and P fertilizers in the intensive cropping system with the diminishing use of organic manures has resulted in the depletion of S from the soil reserves (Upadhyay, 2012). The improper nutrient management has led to emergence of sulphur deficiencies in the soils. The deficiencies of S which were sparse and sporadic initially are now widespread. Sulphur deficiency tends to adversely affect the growth and yield of oil seed crop to an extent of 10-30 per cent due to poor nourishment (Jat *et al.*, 2008, Basumatary *et al.* 2019). The different genotypes of oilseed crops differed significantly in respect to their responses to sulphur application (Misra *et al.,* 2002). Because of short duration life cycle, and photo and thermo-insensitivity, the linseed crop has wider adaptability in different agro-climatic conditions and soil types. The full potential of linseed can be exploited by adopting suitable linseed genotypes with balanced nutrition of sulphur. Keeping the above facts in view, the present investigation was taken up using linseed as test.

MATERIALS AND METHODS

The field experiment was carried out during 2017-18 and 2018-19 at the Private Research Farm, Benda-Semaria Road, Rewa (M.P.). The soil of the experimental field was silty-clay-loam having pH 7.5, electrical conductivity 0.32 dS m^{-1}, organic carbon 0.86 g kg^{-1}, available N, P_2O_5 and K_2O 230, 13.8 and 372 kg ha^{-1}, respectively. The rainfall received during the rainy season was 760 and 752 mm in 2017 and 2018, respectively. The treatments comprised five genotypes (JLS-67, JLS-27, RLC-91, JLT-84-12-5, JLT-84-5) and four levels

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of sulphur (0, 20, 40 and 60 kg ha^{-1}). Thus, the twenty treatment combinations were laid out in the field in a factorial randomised block design keeping three replications. The linseed genotypes were sown on 25 and 15 November in 2017 and 2018, respectively @ 6 kg ha^{-1} in rows 30 cm. The sulphur levels were applied as basal through elemental sulphur. The common dose of 40 kg N, 30 kg P_2O_5 and 20 kg K_2O ha^{-1} was applied in all the treatments. The crop was raised as per recommended package of practices. The genotypes were harvested on 9 April, 2018 and 2 March, 2019. Yield attributed and seed yield were recorded at harvest The oil percentage in linseed seeds was determined by Soxhlet's extraction method. The seed protein was determined by multiplying the per cent N content in seed with 6.25. Oil and protein yields were computed by multiplying their content values with seed yield.

RESULTS AND DISCUSSION

Growth parameters

The data (Table 1) reveal that amongst the genotypes, JLS-67 attained the significantly maximum height (81.87 cm), primary and secondary branches 7.20 and 46.64 $plant^{-1}$, respectively and produced significantly maximum leaves 580 $plant^{-1}$ at 95 DAS stage. This was followed by JLS-27, RLC-91 and then JLT-84-12-5. The significant variation of all these traits among the different genotypes might be due to attainment of variable growth characters which are genetically controlled in different genotypes developed from different parental origins. The remarkable increase in plant height in case of genotype JLS-67 and then JLS-27 may be acceleration of cell elongation and cell division. Due to maximum increase in leaves per plant in those genotypes, the photosynthetic surface area of the leaves per plant was eventually highest. Such type of variability in growth characters of linseed and mustard genotypes has also been observed by many research workers (Singh and Singh, 2011; Tripathi *et al.*, 2010). At 95 DAS, the highest S-level brought about significantly higher plant height (73.93 cm), primary branches (6.02 $plant^{-1}$), secondary branches (41.80 $plant^{-1}$) and leaves (512 $plant^{-1}$), chlorophyll content (6.55 mg g^{-1}) and dry matter $plant^{-1}$ (17.36 g). The significant increase in all these parameters under increased level of applied sulphur might be due to the fact that it plays vital role in different physiological and chemical functions in plants. According to Rakesh *et al.* (2016), sulphur plays an important role in growth and development of crops as it is constituents of amino acids like methionine, cystein and cystine needed for the synthesis of other metabolism like co-enzyme-A, thiamine and glutathione and also required for synthesis of chlorophyll. Thus, this element is needed in plants for oxidation-reduction reactions, chlorophyll formation and in protein synthesis (Kumar and Trivedi, 2011 and Pandey and Ali, 2012).

Table 1: Growth and yield-attributing parameters of linseed as influenced by genotypes and sulphur levels (Mean of 2 years)

Treatments	Plant height (cm) at 95 DAS	Primary branches $plant^{-1}$ at 95 DAS	Secondary branches $plant^{-1}$ at 95 DAS	Leaves $plant^{-1}$ at 95 DAS	Capsules $plant^{-1}$	Seeds $capsule^{-1}$	1000-seed weight (g)	Seed yield $plant^{-1}$ (g)
				Genotypes				
JLS-67	81.87	7.20	46.64	580	122.8	10.50	7.46	9.04
JLS-27	76.83	6.44	44.35	539	116.1	9.88	7.12	8.20
RLC-91	72.62	5.70	40.72	501	110.6	9.45	6.89	7.55
JLT-84-12-5	67.09	5.04	36.65	453	106.1	8.95	6.75	6.99
JLT-84-5	61.17	4.44	33.37	409	101.4	8.74	6.64	6.60
CD (P=0.05)	0.024	0.026	0.011	0.48	0.32	0.026	0.020	0.019
				Sulphur (kg/ha)				
0	69.80	5.50	38.92	477	109.2	9.28	6.87	7.42
20	71.33	5.68	39.81	493	110.4	9.41	6.94	7.58
40	72.58	5.84	40.86	503	112.1	9.58	7.00	7.76
60	73.93	6.02	41.80	512	114.0	9.75	7.07	7.93
CD (P=0.05)	0.021	0.023	0.010	0.43	0.28	0.023	0.018	0.017

The increase in growth parameters under sulphur fertilization might be due to improved sulphur availability, which in turn enhanced the plant metabolism and photosynthetic activity resulting in better growth (Solanki and Sharma, 2016 and Sahoo *et al.*, 2018).

Yield-attributing parameters

The genotype, JLS-67 resulted in significantly higher number of capsules (122.8 plant^{-1}), seeds (10.50 capsule^{-1}), 1000-seed weight (7.46 g) and seed yield (9.04 g plant^{-1}). The second and third best genotypes were JLS-27 and RLC-91, respectively with respect to yield-attributes (Table 1). The genotypes differed in their growth and yield-attributing potential depending upon many physiological processes which are controlled by both genetic make up and the agro-climatic environment. The different genotypes of linseed have been found to differ significantly in the yield-attributing characters as observed by several researchers (Tripathi *et al.*, 2010; Singh and Singh, 2011; and Singh *et al.*, 2015). All the S-levels also enhanced all these parameters significantly over S_0 (control). The higher number of capsules/plant, seeds/capsule, 1000-seed weight and seed yield/plant may be attributed to the significant role of sulphur in regulating the photosynthesis, enhanced the metabolic activities promoting chlorophyll formation and photosynthesis at one hand and root development coupled with accelerated nutrients absorption on the other. Moreover, this has resulted in higher uptake of nutrients and maintained better harmony between photosynthesis and translocation, and ultimately given rise to higher yield-attributing parameters of linseed. According to Solanki and Sharma (2016), the supply of sulphur in adequate and appropriate amount helps in flower primordial initiation for its reproductive part, which in turn governs the yield-attributes.

Productivity of linseed

Amongst the linseed genotypes, JLS-67 recorded maximum seed yield (16.95 q ha^{-1}), straw yield (29.88 q ha^{-1}) and harvest index (36.19%). Out of these, seed yield, straw yield and harvest index were found significantly higher in case of JLS-67. The second best genotype was, of course, JLS-27 and then RLC-91 (Table 2). The higher productivity parameters in case of JLS-67 and JLS-27 might be attributed to increased vegetative growth, thereby yield-attributing characters viz., number of capsules plant^{-1}, 1000-seed weight, number of seeds capsule^{-1} and weight of grains plant^{-1} in these genotypes. Yield obtained from both the genotypes was higher than those of other genotypes which might be due to their physiological role in increased synthesis and partitioning of the biomass. This was followed by the third best genotype RLC-91 based on all these yield-attributing characters. The yield variations among the linseed genotypes have also been reported by several research workers (Tripathi *et al.*, 2010; Singh and Singh, 2011; Somnath and Goutam, 2012; and Singh *et al.*, 2015). Linseed, a high oil and protein rich crop, needed large quantity of sulphur. In the present experiment, seed and straw yield as well as harvest index of linseed were found to increase significantly with the increased levels of sulphur upto S_{60}. The increase in grain, straw yield (15.65 and 29.05 q ha^{-1}, respectively) and harvest index (35.01%) was mainly due to increase in the yield-attributing characters viz., number of capsules plant^{-1}, 1000-seed weight, number of seeds capsule^{-1} and seed weight plant^{-1} under the highest level of sulphur. The higher harvest index indicates that the S-levels enhanced the transformation of biomass into seed.

Application of S caused proportionately greater increase in grain than in non-grain parts which resulted in higher harvest index of linseed. The interactions between genotypes x sulphur application were found to be positive and significant in increasing the seed and straw yield as well as harvest index. This showed the synergistic relationship between high-yielding genotypes with applied sulphur levels. The significant response to applied sulphur on yield-attributes and yield of linseed was due to the fact that it is a constituent of amino acids and thus vital for protein production. Rathore *et al.*, (2015) also supported the fact that sulphur plays an important role in chlorophyll formation, carbohydrate metabolism, and synthesis of protein. The results are in conformity with those of many research workers (Tripathi *et al.*, 2010; Jyoti *et al.*, 2012; Pachauri *et al.*, 2012; Chattopadhyay and Ghosh, 2012; Verma *et al.*, 2012; Singh *et al.*, 2017 and Sahoo *et al.*, 2018).

Table 2: Yield and quality of linseed as influenced by genotypes and sulphur levels (Mean of 2 years)

Treatments	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})
Genotypes							
JLS-67	16.95	29.88	36.19	43.81	742.6	19.69	2.80
JLS-27	19.39	29.20	35.95	43.59	714.6	18.30	2.71
RLC-91	15.47	28.75	34.99	43.09	666.9	17.61	2.56
JLT-84-12-5	14.41	28.34	33.70	42.96	619.3	16.76	2.39
JLT-84-5	13.33	28.05	32.20	42.34	564.5	16.64	2.21
CD (P=0.05)	0.018	0.014	0.019	0.0011	0.069	0.003	--
Sulphur levels (kg/ha)							
0	14.96	28.64	34.24	41.88	627.1	17.21	2.59
20	15.17	28.77	34.44	42.75	649.0	17.61	2.55
40	15.43	28.92	34.73	43.68	674.5	18.00	2.51
60	15.68	29.05	35.01	44.31	695.5	18.37	2.48
CD (P=0.05)	0.016	0.013	0.017	0.0009	0.062	0.003	--
Interaction	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	--

Seed quality

The genotype JLS-67 resulted in significantly higher oil content in seed (43.81%) and oil yield (742.6 kg ha^{-1}). Protein content in seed (19.69%) and protein yield (333.7 kg ha^{-1}). The second and third best genotypes were JLS-27 and RLC-91, respectively with respect to nutritional quality of seed. The JLT-84-12-5 and JLT-84-5 attained the fourth and fifth position, respectively. Thus, the JLS-84-5 recorded the lowest oil content (42.34%), oil yield (564.5 kg ha^{-1}), protein content (16.64%) and protein yield (221.8 kg ha^{-1}). The variation in grain protein content among these genotypes might be owing to the differences in the synthesis of protein through amino acids as a result of N-metabolism. In case of variation in grain oil content among the genotypes might be due to variation in the synthesis of fatty acids and their esterification by accelerating biochemical reactions in glyoxalate cycle. Seed oil (44.31%) and seed protein (18.36%) both were found to enhance upto significantly extent due to increasing levels of sulphur upto S_{60}. According to Solanki and Sharma (2016), sulphur is a constituent of protein and plays an important role in oil synthesis. Besides performing many physiological functions like synthesis of cysteine, methionine and chlorophyll in oilseed crops, sulphur also plays an important role in the formation of amino acids, synthesis of certain vitamins like biotin, thiamine and protein. The increase in oil content in linseed due to sulphur application upto S_{60} could be due to the fact that S helped in the synthesis of fatty acids and their esterification by accelerating biochemical reactions in glyoxalate cycle. The increase in oil content in linseed with S application might be due to the fact that S helped in oil synthesis by enhancing the level of thioglucosides. The increase in oil content on addition of S was probably due to the increase in glycosides. Similar increases in protein and oil contents in linseed due to increasing levels of sulphur have been supported by many research workers (Kumar *et al.*, 2009 and Pandey *et al.*, 2012).

Application of sulphur consistently increased the protein and oil contents in soybean grain resulting in maximum content of protein as well as oil (Sharma, 2003). Basumatary et al 2019 further reported that sulphur is required for sulphur-containing amino acids, cystine, cysteine and methionine and also for protein synthesis. Sulphur also takes part in the nitrogen metabolism of the plant. Several workers (Pandey *et al.*, 2012, Rakesh *et al.*, 2016 and Sahoo *et al.*, 2018) also reported an increase in oil and protein contents due to sulphur application.

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