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RESEARCH PAPER

Response of sesame to different levels and methods of boron application

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Abstract: A field experiment was conducted during the *kharif* season of 2015 at Main Agricultural Research Station, Dharwad to study the effect of soil and foliar application of boron on growth and yield of sesame. The experiment was laid out in factorial Randomized Complete Block Design with two factors and three replications. Soil application of RDF + 3 kg borax/ha recorded higher grain yield (956 kg/ha).Foliar spray of 0.2 per cent solubor at flowering stage (917 kg/ha) found better than without solubor spray (824 kg/ha). Higher sesame yield was obtained with RDF + 3 kg borax soil application along with foliar spray (1023 kg/ha) recorded. The same treatment also recorded higher length of capsules, number of capsules per plant and seed weight per plant. Highest net returns was possible with the application RDF + 3 kg borax soil application (₹ 38,242/ha) with benefit cost ratio (3.00) and was on par with application of RDF + 3 kg borax soil application along with 0.2 per cent solubor foliar spray (₹ 41,108/ha) with the benefit cost ratio of 3.03.Application of RDF + 3 kg borax ha^{-1} along with 0.2 per cent solubor foliar spray at flowering (45- 50 DAS) was found more optimum for getting higher seed yield with the higher net return and benefit cost ratio.

Key words: Borax, Enrichment, Foliar spray, Sesame

Introduction

Sesame is the world's oldest spice and an ancient oilseed crop mainly known for its oil (48-55%) and protein content (25%). Sesame seeds are rich in source of nutrition, edible oil and bio medicine. It is recognized by various names like gingelly, til, simsim, biniseed *etc*. It is also called as "Queen of oilseed". Sesame seeds have high poly unsaturated fatty acids which in turn give resistance to rancidity. In India, sesame is grown with an area of 0.19 m ha with a production of 0.081 m tonnes. The average yield of sesame in India is very low (426.1 kg/ha^{-1}). It is widely cultivated in the states of Maharashtra, Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Madhya Pradesh, Tamil Nadu and Karnataka. The area of sesame in Karnataka is 0.67 lakh ha with an annual production of 0.31 lakh tonnes with a productivity of 500 kg/ha^{-1} ha (Anon., 2015).

Boron is one of the seven essential micronutrients required for normal growth of most plants. Boron deficiency is the most widespread among micronutrients around the world and causes large losses in crop production both quantitatively and qualitatively, which is associated with the pollen producing capacity of anther, viability of pollen tubes, pollen tube germination and growth of pollen tube. Reduction in supply of boron decreases the oil production and impairs the quality of oil (Soleimani, 2006). India has thirty three per cent of boron deficient soils, 39% of soils in Bihar are deficient in B, 68% of soils in West Bengal, 24.5% in Uttar Pradesh, 21% in Tamil Nadu,1.5% in Harayana and 32 % in Karnataka soils are deficient in boron (Anon., 2015). Use of organics like FYM, vermicompost *etc.,* along with inorganic fertilizers is the optimum method of applying nutrients. However, as the nutrient content of organics is small, their additions at a lower rate do not meet the nutrient requirement of crops. Under such situation an alternative technology which suggests the minimum possible use of inorganic fertilizers with organics would be of paramount importance for small and marginal farmers. The process of enrichment of organics with micronutrients not only improves the nutrient use efficiency but also helps in reducing the load of inorganic fertilizers as well as quantity of organics to a considerable extent (Meena, *et al.,* 2006). Foliar fertilization is gaining more importance in recent years due to the availability of soluble fertilizers and is of great significance in rainfed areas under changing climatic conditions. Foliar feeding is often effective when roots are unable to absorb sufficient nutrients from the soil due to moisture deficiency and foliar fertilization is also a better option when the crop height is more (White *et. al.,* 2013). Application of nutrients through foliar spray helps in quick regain in drought situation and also prevents the loss of nutrients in the soil. In the past 30 years, research on the relation of boron with plant nutrition has progressed significantly, and the application of boron-containing fertilizers has become a standard measure in many boron-deficient regions (Wang, 2013). Present study was conducted to know the effect of farm yard manure (FYM) enrichment with or without borax soil application along with or without solubor foliar spray on sesame.

Material and methods

A field experiment was conducted during the kharif season of 2015 in Main Agricultural Research Station, College of Agriculture Dharwad, situated at 15°26' N latitude, 75°07' E longitude and at an altitude of 678 m above mean sea level. The location of the experimental site is situated under Northern Transition Zone of Karnataka which lies between the Western Hilly Zone and Northern Dry Zone. The rainfall during cropping period was 259.6 mm which ensured adequate stored moisture for germination, emergence and early establishment of seedlings. The mean maximum temperature recorded during the period of experimentation was ranged from 28.9°C (July)

to 28.7°C (August), while the minimum temperature was ranged from 20.6°C (June) to 21.2°C (August). The soil of the experimental site was clay loam soil with the clay content (60.5 %). The experiment was laid out in randomized complete block design with factorial concept with six levels of soil application and two levels of foliar spray replicated thrice.

Factor 1: Soil application of borax with or without enrichment

B_1: RDF + FYM enrichment with borax at the rate of 1 kg per hectare; B_2: RDF + FYM enrichment with borax at the rate of 2 kg per hectare; B_3: RDF + FYM enrichment with borax at the rate of 3 kg per hectare; B_4: RDF + 1 kg Borax; B_5: RDF + 2 kg Borax; B_6: RDF + 3 kg Borax

Factor 2: Foliar application of solubor:F_0: No spray;F_1: Solubor spray @ 0.2 percent at flowering stage; Control : RDF(FYM @ 5 t ha^{-1} + 50: 25: 25 kg ha^{-1}N: P_2O_5: K_2O)

The sesame variety DS- 5was used in the experiment.The crop was thinned at 15 days after sowing to maintain spacing of 10 cm between plants.Recommended package of practices were followed to raise the successful crop.

Results and discussion

Yield and yield attributes

Yield attributes of sesame i.e. number of capsules per plant, length of capsules and seed weight per plant was significantly influenced by soil application of borax and foliar application of solubor (Table1). Application of RDF + 3 kg borax soil application recorded significantly higher (103, 2.46 cm and 10.26 g respectively), length of capsules and this was found on par with the application of RDF + 2 kg borax soil application. Foliar application of 0.2% solubor spray at flowering stage recorded higher number of capsules, length of capsules and seed weight per plant (99.75, 2.32 cm and 9.74 g respectively) than no foliar spray. Significantly higher numberof capsules (108.05) were recorded with the application of RDF + 2 kg borax soil application without foliar spray than all other interactions. Length of capsules per plant were recorded highest with the application of RDF + 3 kg borax soil application along with 0.2% solubor foliar spray (2.47 cm) and was found par with application of RDF + 3 kg borax soil application without foliar spray (2.45 cm). Significantly higher seed yield per plant was recorded with the application of RDF + 3 kg borax / ha along with 0.2% solubor foliar spray (10.48 g) than all other interaction treatments. Higher seed yield per plant, length of capsules and number of capsules per plant in soil applications and FYM enrichment might be due to boron availability and photosynthetic activity leading to production and accumulation of more carbohydrates and auxins which favours retention of more flowers ultimately leading to more number of reproductive parts per plant and yield. Higher number of capsules per plant, number of seeds per capsule and 1000 seed weight was increased when boron was applied @ 7.5 kg/ha with 25% of RDF through FYM (Mamatha *et al.,* 2017).

Sesame seed yield, stalk yield, harvest index and oil content were found to be significant with the soil application of borax and foliar application of solubor (Table 2). Application of RDF + 3 kg borax to soil recorded significantly higher sesame seed yield (956 kg/ha) than soil application of RDF + 1 and 2 kg borax/ ha (897 and 879 kg/ha respectively). Lower seed yield was recorded with the application of RDF + FYM enrichment with borax 1 kg/ha (722 kg/ha). Application of 0.2% solubor foliar spray recorded higher grain yield (917 kg/ha) compared to no foliar spray (824 kg/ha). Interaction effect was found significant for sesame yield. Application of RDF + 3 kg borax soil application along with 0.2% solubor foliar spray recorded significantly higher seed yield (1023 kg/ha) which was found on par with all the treatments receiving foliar spray except with

Table 1. Effect of different methods of boron fertilization on seed yield and its related parameters of sesame at 90 DAS

Soil application	No of capsule per plant Foliar fertilization			Length of capsule (cm) Foliar fertilization			Seed yield per plant (g) Foliar fertilization		
	F_0	F_1	Mean	F_0	F_1	Mean	F_0	F_1	Mean
B_1	85.15	93.70	89.43	1.94	2.35	2.15	8.69	9.70	9.20
B_2	89.10	102.85	95.98	2.10	2.32	2.21	8.68	9.39	9.03
B_3	92.55	101.30	96.93	2.09	2.19	2.14	8.57	9.77	9.17
B_4	92.35	99.30	95.83	2.07	2.41	2.24	8.55	9.61	9.08
B_5	108.05	98.85	103.45	1.95	2.22	2.08	9.69	9.49	9.59
B_6	103.50	102.50	103.00	2.45	2.47	2.46	10.04	10.48	10.26
Mean	95.12	99.75		2.10	2.32		9.04	9.74	
Control (RDF alone)	71.95	1.64	6.95						
	S.Em±	C.D. (p=0.05)		S.Em±	C.D. (p=0.05)		S.Em±	C.D. (p=0.05)	
Soil application	0.98	2.81		0.07	0.20		0.09	0.27	
Foliar spray	0.56	1.62		0.04	0.11		0.05	0.15	
Soil x foliar	1.38	3.97		0.10	0.28		0.13	0.38	
Treatment Vs control	1.34	3.84		0.09	0.27		0.14	0.39	

F_0 - No foliar spray
F_1- 0.2% solubor foliar spray at flowering stage
B_3 - RDF + FYM enrichment with borax 3 kg ha^{-1}
B_1- RDF + FYM enrichment with borax 1 kg ha^{-1}
B_2- RDF + FYM enrichment with borax 2 kg ha^{-1}
B_6 - RDF + borax 3 kg ha^{-1}
B_4 - RDF + borax 1 kg ha^{-1}
B_5 - RDF + borax 2 kg ha^{-1}
Control- RDF (FYM @ 5 t ha^{-1} + 50: 25: 25 kg ha^{-1}N: P_2O_5: K_2O)

Table 2. Effect of different methods of boron fertilization on seed yield, stalk yield, harvest index and oil content of sesame at harvest

Soil application	Seed yield (kg/ha) Foliar fertilization			Stalk yield (kg/ha) Foliar fertilization			Harvest index (%) Foliar fertilization			Oil content (%) Foliar fertilization		
	F_0	F_1	Mean	F_0	F_1	Mean	F_0	F_1	Mean	F_0	F_1	Mean
B_1	712	732	722	2503	2530	2516	28.39	29.04	28.72	51.71	52.64	52.18
B_2	767	897	832	2533	2587	2560	30.45	35.04	32.75	49.73	51.10	50.42
B_3	893	979	936	2613	2685	2649	34.22	36.60	35.41	51.68	50.90	51.29
B_4	837	957	897	2697	2669	2683	31.47	35.97	33.72	48.54	50.75	49.64
B_5	845	912	879	2750	2803	2776	31.04	32.75	31.90	53.55	50.54	52.05
B_6	890	1023	956	2746	2656	2701	32.59	38.52	35.56	48.64	53.33	50.98
Mean	824	917		2640	2655		31.36	34.65		50.64	51.54	
Control (RDF alone)		703			2742			25.81			50.35	
	S.Em±	C.D. (p=0.05)		S.Em±	C.D. (p=0.05)		S.Em±	C.D. (p=0.05)		S.Em ±	C.D. (p=0.05)	
Soil application	27.24	78.36		53.46	153.83		1.28	3.69		0.77	2.23	
Foliar spray	15.72	45.24		30.87	NS		0.74	2.13		0.45	NS	
Soil x foliar	38.52	110.82		75.61	217.54		1.81	5.22		1.10	3.15	
Treatment Vs control	44.40	127.34		75.32	NS		2.06	5.91		1.11	NS	

F_0 - No foliar spray
F_1- 0.2% solubor foliar spray at flowering stage

B_1- RDF + FYM enrichment with borax 1 kg ha^{-1}
B_2- RDF + FYM enrichment with borax 2 kg ha^{-1}
B_3 - RDF + FYM enrichment with borax 3 kg ha^{-1}

B_4 - RDF + borax 1 kg ha^{-1}
B_5 - RDF + borax 2 kg ha^{-1}
B_6 - RDF + borax 3 kg ha^{-1}

Control- RDF (FYM @ 5 t ha^{-1} + 50: 25: 25 kg ha^{-1}N: P_2O_5: K_2O)

RDF + FYM enrichment with borax 1 kg/ha along with foliar spray (732 kg/ha). The differences in sesame yield were significant within the FYM enriched treatments and also within soil applied treatments and higher seed yield was due to the higher yield attributing characters like number of capsules per plant, length of capsules and seed weight per plant. Mathew and Suman (2013) under Entisols of Kerala applied boron at 2.5 kg ha^{-1} with recommended dose of fertilizers and found increase in the sesame seed yield (1,109 kg ha^{-1}) and harvest index (23.4 %).

Application of RDF + 2 kg borax ha^{-1} recorded higher stalk yield (2,776 kg ha^{-1}) and was on par with RDF + 3 kg borax ha^{-1} (2,701 kg ha^{-1}). Foliar spray of 0.2% solubor spray recorded higher stalk yield (2,655 kg ha^{-1}) as compared with no foliar spray application (2,640 kg ha^{-1}). Soil application of RDF + 2 kg borax along with 0.2 per cent solubor foliar spray recorded significantly higher stalk yield (2,803 kg/ha) which found on par with all other treatments except with the application of RDF + FYM enrichment with 1 and 2 kg/ha borax soil application without solubor foliar spray (2,503 kg/ha and 2,533 kg/ha respectively). Sahu *et.al.* (2017) noticed improvement in stover yield of sesame from 15.93 q/ha to 17.47 q/ha when boron was applied along with FYM under West Bengal conditions and this increase was to an extent of 9.6%. Significantly higher harvest index was observed in treatment receiving RDF + 3 kg borax ha^{-1} (35.56 %) and this was found on par with all treatments except RDF + FYM enrichment with 1 kg borax ha^{-1} (28.72 %). Foliar application of 0.2 per cent solubor spray at flowering stage recorded significantly higher harvest index (34.65) when compared to no foliar spray application (31.36%). Significantly higher harvest index was recorded with the application of RDF + 3 kg borax/ ha^{-1} (35.56%) and found on par with all other soil application treatments. Lower harvest index was recorded with the application of RDF + FYM enrichment with 1 kg borax soil application (28.72%). Foliar spray of 0.2% solubor at flowering stage recorded higher harvest index (34.65%) than no foliar spray. Significantly higher harvest index was recorded with application of RDF + 3 kg borax/ha along with foliar spray (38.52 %) and found on par with all other interaction treatments receiving foliar spray except with the application of RDF + FYM enrichment with 1 kg borax soil application along with solubor foliar spray (29.04%). Soil application of boron recorded significantly higher oil content in the treatment receiving RDF + FYM enrichment with 1 kg borax ha^{-1} (52.18 %) and found on par with the all other treatments except the treatment receiving RDF + 1 kg borax ha^{-1} (49.64) which recorded lower oil content. Foliar application of solubor 0.2 per cent at flowering stage had no significant difference on oil content of sesame. Application of RDF + 2 kg borax soil application without foliar spray recorded higher oil content (53.55%) and found on par with application of RDF + 2 kg borax soil application along with 0.2 percent solubor foliar spray (53.33%). Lower oil content was recorded with the application of RDF + 1 and 3 kg/ha borax soil application without foliar spray (48.54 and 48.64 % respectively). The oil content within FYM enrichment treatments or within soil application treatments did not vary probably because of sufficient availability of boron to attain maximum oil content in the sesame seeds. Soil application of boric acid and sodium borate recorded higher oil content of 40.6 % (Brighenti and Castro, 2008).

Economics: The economic analysis as influenced by different levels and methods of borax and solubor application is indicated in table 3. Soil application of boron in sesame production indicated that maximum gross returns (₹ 57,380 ha^{-1}) with the application of RDF + 3 kg borax ha^{-1} and net returns of ₹ 38,242/ha with benefit cost ratio of 3.00. This was due to higher sesame yield in this treatment in comparison to other treatments. Foliar application of 0.2 per cent solubor spray at flowering recorded highest gross returns (₹ 55,008/ha) and net returns (₹ 35,110/ha) with benefit cost ratio (2.79) as compared

Table 3. Economics of sesame as influenced by different methods of boron fertilization

Soil application	Gross returns (₹/ha) Foliar fertilization			Net returns (₹/ha) Foliar fertilization			B : C Ratio Foliar fertilization		
	F_0	F_1	Mean	F_0	F_1	Mean	F_0	F_1	Mean
B_1	42690	43945	43318	25362	24397	24880	2.46	2.25	2.36
B_2	46038	53823	49930	28360	33926	31142	2.60	2.70	2.65
B_3	53571	58761	56166	35543	38513	37028	2.97	2.90	2.94
B_4	50223	57422	53823	32895	37874	35385	2.90	2.94	2.92
B_5	50725	54743	52734	33047	34845	33946	2.87	2.75	2.81
B_6	53404	61356	57380	35376	41108	38242	2.96	3.03	3.00
Mean	49442	55008		31764	35110		2.76	2.79	
Control (RDF alone)		42188			25410			2.51	
	S. Em±	C.D. (p=0.05)		S. Em±	C.D. (p=0.05)		S. Em±	C.D. (p=0.05)	
Soil application	1634.15	4701.83		1634.15	4701.83		0.09	0.27	
Foliar spray	943.48	2714.60		943.48	2714.60		0.05	NS	
Soil x foliar	2311.03	NS		2311.03	NS		0.13	0.38	
Treatment Vs control	2663.79	7640.18		2663.79	7640.18		0.15	0.43	

F_0 - No foliar spray
F_1- 0.2% solubor foliar spray at flowering stage
B_1- RDF + FYM enrichment with borax 1 kg ha^{-1}
B_2- RDF + FYM enrichment with borax 2 kg ha^{-1}
B_3 - RDF + FYM enrichment with borax 3 kg ha^{-1}
B_4 - RDF + borax 1 kg ha^{-1}
B_5 - RDF + borax 2 kg ha^{-1}
B_6 - RDF + borax 3 kg ha^{-1}
Control- RDF (FYM @ 5 t ha^{-1} + 50: 25: 25 kg ha^{-1}N: P_2O_5: K_2O)

to no foliar spray treatment. Application of RDF + 3 kg borax ha^{-1} along with foliar spray recorded the higher gross returns of ₹ 61,356 $ha^{-1}$and net returns of ₹ 41,108/ha with benefit cost ratio of 3.03 as compared to other interactions, which was followed by the application of RDF + FYM enrichment with 3 kg borax ha^{-1} with foliar spray (₹ 58,761 ha^{-1}) and net returns of ₹ 38,513/ ha with benefit cost ratio of 2.90. Highest gross returns, net returns and benefit cost ratio were obtained in the treatment plots as compared to control plots. This might be due to increase in grain yield as a result of better utilization of both applied and native nutrients. Treatment receiving soil application of borax had beneficial effect on increasing net returns and B: C ratio. Highest net returns and benefit cost ratio might be due to the application of foliar nutrients directly to foliage which increased the seed yield of the crop which further increased the net monetary returns and the benefit cost ratio. Application of 2.5 kg ha^{-1} boron along with RDF resulted in higher net returns (₹ 19,200 ha^{-1}) and BC ratio (2.4) in sunflower in comparison to control (Sagar *et al*., 1986).

Application of recommended dose of fertilizer (RDF) + 3 kg borax as soil application along with 0.2% solubor foliar apray at flowering stages of sesame was found optimum for getting better growth, yield attributes, yield oil content, higher net returns and benefit cost ratio in medium to deep black soils in *kharif* season.

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