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Effect of Foliar Application of Micro Nutrients on Yield and Yield Attributes of Sesame (*Sesamum indicum* L.) under drought Stress

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ABSTRACT: A field experiment was conducted during *rabi* season 2023, at Agricultural College, Bapatla to study the effect of micro nutrients as foliar spray, on yield and yield attributes of sesame crop under drought stress. The field experiment was laid out in a Split Plot design with three replications. There are two main treatments *i.e.*, no stress (M_1- irrigation is given as per irrigation schedule), and moisture stress at flowering and capsule formation stages *i.e.*, 35-60 DAS (M_2) and eight sub treatments *viz.*, no application of micro nutrients (control - S_1), foliar application of $ZnSO_4$ @3000 ppm (S_2), H_3BO_3 @2000ppm (S_3), $NiCl_2$ @5 ppm (S_4), $FeSO_4$ @3 ppm (S_5), Na_2MoO_4 @0.5 ppm (S_6), $ZnSO_4$ @3000 ppm+H_3BO_3 @2000ppm (S_7) and $ZnSO_4$ @3000ppm+H_3BO_3 @2000ppm+$NiCl_2$ @5 ppm+$FeSO_4$ @3 ppm+Na_2MoO_4 @0.5ppm (S_8) at 50 DAS. All treatments recorded significantly higher yield and yield components over control. Among all treatments, S_8 recorded significantly higher yield and yield components compared to other treatments.

Keywords: Sesame, foliar application, yield and yield attributes and drought.

INRODUCTION

Sesame (*Sesamum indicum* L.) is one of the most important oil seed crops and also called as queen of oil seeds, widely grown in different parts of the country and the world. Sesame is the second most important oil-producing crop in India. Sesame is a rich source of anti-oxidants, oil (40-50%), proteins (8%), vitamins and minerals like iron, copper and zinc which are very much useful in human and animal nutrition (Weiss, 2000). In India the sesame crop is grown in *kharif* and as well as summer.

Sesame is grown in an area of 4.27 lakh hectares with 7.29 lakh metric tonnes of production in India during 2020-21 (https://www.indiastat.in) and occupied 2nd position in production in the world. More than 85% of production comes from West Bengal, Madhya Pradesh, Uttar Pradesh, Telangana and Andhra Pradesh. Among the states, Andhra Pradesh has been occupied an area of 0.36 lakh hectares with production of 0.09 lakh tonnes during 2020-21 (des.ap.gov.in). In India, the average yield of sesame is less compared to other countries. The main reason for the low productivity of sesame is the poor management of rainfed cultivation in marginal and sub-marginal lands and input starved condition.

Drought is a big challenge in global agricultural production (Hu and Xiong 2014; Leng and Hall 2019) which effects the physical and chemical as well as microbiological parameters of soil fertility and its productivity which are important functions for plant biomass and grain production (Chodak *et al.*, 2015). Drought has been gradually becoming severe in parts of India as well as sesame growing areas of Andhra Pradesh under the dry land situations. Thus, under these conditions, sesame is considered as alternative solution for cultivation under rainfed conditions when compare with to other oil seed crops.

Zinc counteracts the harmful effects of water stress by increasing protein and chlorophyll synthesis and also improving the potential yield of photosystem II (Karami *et al.*, 2016; Dehnavi and Sheshbahre 2017), increasing the antioxidant enzymes content (Ma *et al.*, 2017), improving the leaf proline and soluble carbohydrate contents (Dehnavi and Sheshbahre 2017). Boron is important for protein synthesis, seed and cell wall formation, pollen germination and pollen tube growth (Dordas, 2006). Iron is important component of enzymes promoting assimilation, biological nitrogen fixation and construction of heme and iron-sulfur proteins (Vigani and Zocchi 2010; Briat *et al.*, 2010). Molybdenum is essential for growth of all living organisms, play an important role in enzymatic redox reactions (Williams and da Silva 2000). Molybdenum is cofactor of nitrogenase enzyme that catalyses the reductio of N_2 during nitrogen fixation (Kneip *et al.*, 2007). The essentiality of nickel as a micro nutrient in plants has been established because it is part of the active site of the enzyme urease, which hydrolyses urea in plant tissues. Thus, micro nutrients are necessary for the normal metabolic functions of the plant, but at higher concentrations, these metals are toxic and severely interfere with physiological and biochemical purposes.

MATERIAL AND METHODS

The field experiment was conducted to study the "effect of foliar application of micro nutrients on yield and yield attributes of sesame under drought stress" was conducted during *rabi* season of 2023 at Agricultural College Bapatla. It is geographically located at 15°54′ Northern latitude, and 80°25′ Eastern longitude, with an altitude of 5.49 m above the mean sea level (MSL), which is about 8 km away from the Bay of Bengal in the Krishna Agro-Climatic Zone of Andhra Pradesh. the experiment soil was sandy loam in texture, neutral with a pH of 7.2 and is low in organic carbon. The details of the treatments given below. The experiment was laid out in split plot design replicated thrice. There are two main treatments *i.e.,* no stress (M_1- irrigation is given as per irrigation schedule), and moisture stress at flowering and capsule formation stages *i.e.,* 35-60 DAS (M_2) and eight sub treatments *viz.,* no application of micro nutrients (control - S_1), foliar application of $ZnSO_4$ @3000 ppm (S_2), H_3BO_3 @2000ppm (S_3), $NiCl_2$ @5 ppm (S_4), $FeSO_4$ @3 ppm (S_5), Na_2MoO_4 @0.5 ppm (S_6), $ZnSO_4$ @3000 ppm + H_3BO_3 @2000ppm (S_7) and$ZnSO_4$ @3000ppm +H_3BO_3 @2000ppm +$NiCl_2$ @5 ppm+ $FeSO_4$ @3 ppm+ Na_2MoO_4 @0.5ppm (S_8) at 50 DAS. Total number of capsules was obtained by taking the average number of filled pods counted from each plant of randomly selected five plants per each treatment and the number of seeds were counted and averaged. Capsule length was obtained by taking the average length of capsules from each plant of randomly selected five plants per each treatment. Capsule weight was obtained by taking the average weight of capsules from each plant of randomly selected five plants per each treatment. A lot of seeds was drawn at random from each treatment plot in 3 replications and weighted. Number of seeds constituting the sample was counted and from these values 100 seed weighted was compared. Five plants in each replication were harvested and the seed was separated, cleaned, dried and weighed to the nearest gram to obtain the average seed yield per plant.

RESULTS AND DISCUSSION

A. Number of capsules Plant^{-1}

The data on the number of capsules per plant was presented in Table 1 and Fig. 1. The mean number of capsules per plant were significantly lower under water stress (M_2-30.32) compared to irrigated condition (M_1-39.51). Sesame crop grown under water stress condition recorded 23.2 per cent reduction in mean number of capsules per plant compared to irrigated condition. Among the micro nutrient treatments, foliar application of consortia recorded the highest mean number of capsules per plant (S_8-39.83) which was at par with the foliar application of $ZnSO_4$ - @3000 ppm(S_2 -39.07) followed by foliar application of mixture of zinc and boron (S_7 -37.15). Control without micro nutrient foliar application recorded lower mean number of seeds per capsule (S_1-29.91) which was at par with the foliar application of $NiCl_2$ @ 5 ppm (S_4-32.23) followed by Na_2MoO_4 - @0.5 ppm(S_6-32.55). The remaining treatments S_3 and S_5 were superior over control, S_4 and S_6 and inferior over S_8, S_7 and S_2. In the current study, foliar application of consortia and $ZnSO_4$ - @3000 ppm recorded 33.1 and 30.6 per cent increase in number of capsules per plant, respectively, over control plants. Similarly, the highest number of capsules per plant were observed in zinc foliar application treatments compared to control (no zinc foliar application) (Vaghar *et al*., 2020) in soybean, Valenciano *et al.* (2010) in chickpea and Quddus *et al.* (2011) in mungbean.

B. Number of Seeds Capsule^{-1}

The data on the number of seeds per capsule was presented in Table 1 and Fig. 2. The mean number of seeds per capsule are significantly lower under water stress (M_2- 39.77) compared to irrigated condition (M_1-50.90). Sesame crop grown under water stress condition recorded 22.65 per cent reduction in mean number of seeds per plant compared to irrigated condition. Among the micro nutrient foliar application treatments tested, foliar application of consortia recorded the highest mean number of seeds per capsule (S_8- 48.08) which was at par with the foliar application of $ZnSO_4$ -@3000 ppm (S_2- 47.47) followed by foliar application of FeSO4- @3mg(S_5- 46.29) and foliar application of mixture of zinc and boron (S_7- 45.50). Control without micro nutrient foliar application recorded lower mean number of seeds per capsule (S_1-42.17) which was at par with the foliar application of $NiCl_2$ @ 5 ppm (S_4 - 42.83), Na_2MoO_4 @ 0.5 ppm (S_6 -43.75) and H_3BO_3-@2000ppm (S_3 - 45.02). In the current study, foliar application of consortia recorded 14.0 per cent increase in number of seeds per capsule over control plants. Similarly, the highest number of grains per plant were observed in zinc foliar application treatments compared to control (no zinc foliar application) by Hera *et al.* (2018) in wheat.

Table 1: Effect of foliar application of micro nutrients on yield attributes of sesame under drought stress.

Treatments	Yield attributes								
Sub treatments	Number of capsules plant^{-1}			Number of seeds capsule^{-1}			Test weight (g)		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1-Control	33.67	26.17	29.91	47.19	37.17	42.17	2.54	2.19	2.36
S_2-Foliar application of $ZnSO_4$ -@3000 ppm	44.00	34.14	39.07	53.17	41.78	47.47	3.16	2.27	2.71
S_3-Foliar application of H_3BO_3-@2000ppm	39.00	30.33	34.66	51.25	38.80	45.02	3.17	2.29	2.73
S_4-Foliar application of NiCl2 -@5 ppm	37.25	27.22	32.23	48.00	37.67	42.83	2.88	2.23	2.55
S_5-Foliar application of $FeSO_4$-@3 ppm	38.67	29.17	33.91	52.33	40.26	46.29	3.11	2.26	2.68
S_6-Foliar application of Na_2MoO_4 - @0.5 ppm	36.87	28.25	32.55	49.33	38.16	43.75	3.13	2.25	2.68
S_7-Foliar application of $ZnSO_4$ -@3000 ppm+ H_3BO_3-@2000ppm	42.00	32.30	37.15	52.00	39.00	45.40	3.19	2.32	2.75
S8-Foliar application of ZnSO4 -@3000ppm+H_3BO_3@2000ppm+ $NiCl_2$ - @5 ppm+$FeSO_4$ -@3 ppm+ Na_2MoO_4 - @0.5 ppm	44.67	35.00	39.83	54.00	42.17	48.08	3.21	2.35	2.78
Mean	39.51	30.32		50.90	39.37	39.37	3.04	2.270	
	SEm±	CD (P=0.05)	CV (%)	SEm±	CD (P=0.05)	CV (%)	SEm±	CD (P=0.05)	CV (%)
Main treatment	0.62	3.79	8.75	0.60	3.70	6.61	0.04	0.25	7.75
Sub treatment	1.52	4.40	10.67	1.01	2.92	5.47	0.09	NS	9.12
Interaction	2.15	NS		1.43	NS		0.14	NS	

Foliar application of Zn increased grain yield and number of grains in wheat under drought (Karim *et al.*, 2012). The increasing grain yield was due to the plant obtaining more Zn through the soil or leaf. Application of Zn fertilizer could increase grain yield regardless of soil water supply conditions. Alternatively, sufficiently high Zn is needed to alleviate drought stress by contributing to detoxifification of ROS (Carvalho, 2008).

C. Capsule length

The data on the number of capsule length was presented in Table 2 and Fig. 3. The highest capsule length was recorded in the sesame plants under irrigation (M_1 - 2.31 cm) compared to the plants exposed to drought stress (M_2 – 1.78 cm). Sesame plants subjected to water stress recorded 22.9 per cent reduction in capsule length compared to irrigated treatment during water deficit stress reduced the capsule length. Among the different micro nutrient treatments, foliar application of consortia recorded the highest capsule length (S_8-2.21 cm) and it was at par with the foliar application of mixture of zinc and boron (S_7-2.17 cm), followed by foliar application of zinc @3000 ppm (S_2- 2.11 cm) and boron @ 2000 ppm (S_3- 2.08 cm). whereas, control recorded significantly lower capsule length (S_1-1.89) which was at par with the foliar application of $NiCl_2$ @ 5mg L^{-1}(S_4 -1.92), Na_2MoO_4 @ 0.5 ppm (S_6 - 1.98) and $FeSO_4$-@3mg(S_5- 2.00). In the current study, foliar application of consortia recorded 16.9 per cent increase in capsule length over control plants. Similar type of results were also reported by Hera *et al.* (2018) who found that foliar application of zinc improve the spike length by 1.05 percent under water stress in wheat by improved catalytic activity in anther.

D. Capsule weight

The data on the capsule weight was presented in Table 2 and Fig. 4. Capsule weight of sesame was significantly lower under water stress condition. The highest capsule weight was recorded in the sesame plants under irrigation (0.25 gm) compared to the plants exposed to drought stress (0.15 gm). Sesame plants subjected to water stress recorded 40 per cent reduction in capsule weight compared to irrigated treatment. Among the different micro nutrient treatments, foliar application of consortia recorded the highest capsule weight (S_8- 0.24 gm) and it was at par with the foliar application of mixture of zinc and boron (S_7- 0.23 gm). Lowest capsule weight of 0.16 gm was recorded in control (without micro nutrient application) which was at a par with the foliar application of $NiCl_2$ @ 5 ppm (S_4 – 0.17). In the current study, foliar application of consortia and mixture of zinc and boron recorded 50.0 and 43.7 per cent increase in capsule weight, respectively, over control plants. The remaining treatments (S_2, S_3, S_4, S_5 and S_6) were superior over control and superior over S_8.

E. Test weight

The data on the test weight of the seed was presented in Table 1. The test weight of seed ranged from 2.36 to 2.78. There was significant difference between main treatments and no significant difference among sub treatments and their interactions. Among the main treatments the highest test weight was recorded in irrigation treatment (M_1 – 3.04) compared to water stress treatment (M_2 –2.27). The test weight of seed was 31.90 per cent higher under irrigation conditions compared to the water stress conditions. However, no significant difference was observed among sub treatments with respect to test weight.

Table 2: Effect of foliar application of micro nutrients on yield attributes of sesame under drought stress.

Treatments	Yield parameters								
Sub treatments	Capsule length (cm)			Capsule weight (g)			Seed yield (kg ha^{-1})		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1-Control	2.20	1.59	1.89	0.21	0.12	0.16	653.00	326.33	489.66
S_2-Foliar application of $ZnSO_4$ -@3000 ppm	2.37	1.87	2.11	0.27	0.17	0.22	1272.17	691.67	981.91
S_3-Foliar application of H_3BO_3-@2000ppm	2.33	1.83	2.08	0.26	0.16	0.21	963.50	479.75	721.62
S_4-Foliar application of $NiCl_2$ -@5 ppm	2.22	1.64	1.92	0.22	0.13	0.17	726.00	359.74	542.87
S_5-Foliar application of $FeSO_4$-@3 ppm	2.26	1.75	2.00	0.23	0.14	0.18	1164.00	628.00	896.00
S_6-Foliar application of Na_2MoO_4 -@0.5 ppm	2.24	1.73	1.98	0.24	0.15	0.19	874.67	423.54	649.10
S_7-Foliar application of $ZnSO_4$ -@3000 ppm/ L+ H_3BO_3-@2000ppm	2.43	1.91	2.17	0.28	0.18	0.23	1093.33	564.67	829.00
S8-Foliar application of $ZnSO_4$-@3000ppm+H_3BO_3@2000ppm+ $NiCl_2$ - @5 ppm+$FeSO_4$ -@3 ppm+ Na_2MoO_4 - @0.5 ppm	2.50	1.93	2.21	0.29	0.19	0.24	1410.00	753.00	1081.50
Mean	2.31	1.78		0.25	0.15		1019.58	528.33	
	SEm±	CD (P=0.05)	CV (%)	SEm±	CD (P=0.05)	CV (%)	SEm±	CD (P=0.05)	CV (%)
Main treatment	0.03	0.18	7.29	0.00	0.01	6.69	17.29	105.25	10.94
Sub treatment	0.06	0.18	7.47	0.00	0.01	5.37	31.43	91.06	9.94
Interaction	0.09	NS		0.00	NS		44.45	128.78	

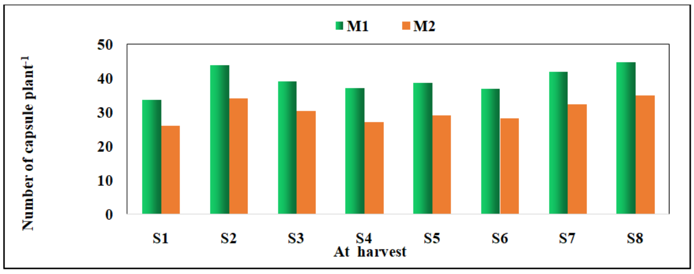

Fig. 1. Effect of foliar application of micro nutrients on number of capsules per plant of sesame under drought stress.

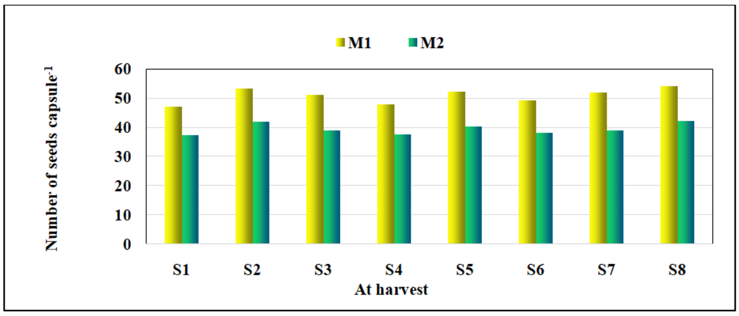

Fig. 2. Effect of foliar application of micro nutrients on number of seeds per capsule of sesame under drought stress.

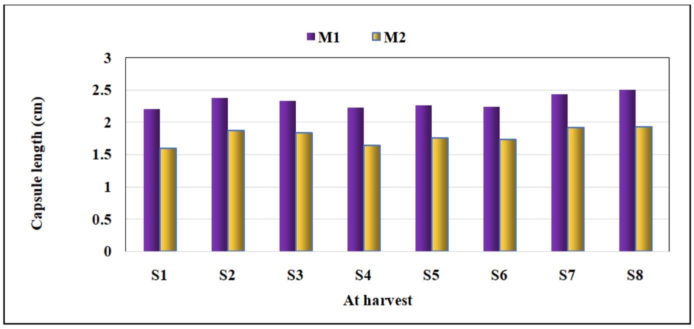

Fig. 3. Effect of foliar application of micro nutrients on capsule length (cm) of sesame under drought stress.

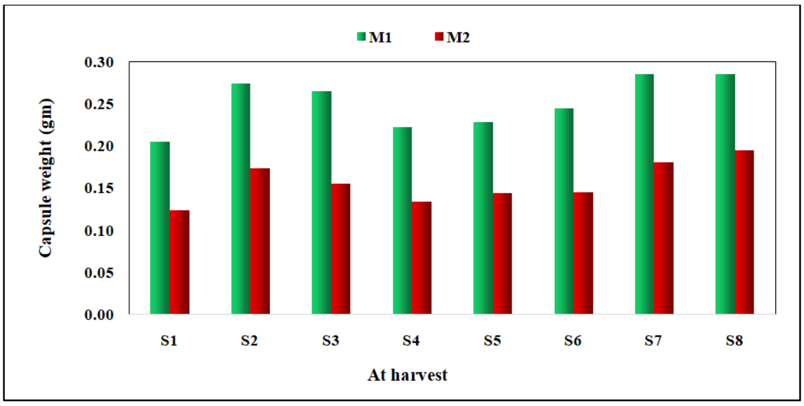

Fig. 4. Effect of foliar application of micro nutrients on capsule weight (gm) of sesame under drought stress.

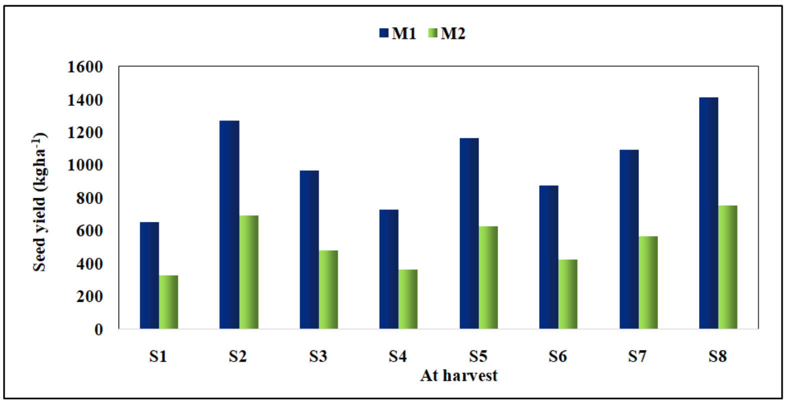

Fig. 5. Effect of foliar application of micro nutrients on seed yield (kg ha^{-1}) of sesame under drought stress.

F. Seed yield

The data on the seed yield was presented in Table 2 and Fig. 5. The seed yield was significantly low under drought stress (M_2-528.33 kg ha^{-1}) compared to irrigated condition (M_1-1019.58 kg ha^{-1}). Sesame crop under water stress recorded 48.1 per cent reduction in seed yield compared to irrigation treatment. Among the micro nutrient treatments, seed yield of sesame ranged from 489.66 to 1081.50 kg ha^{-1}. Foliar application of consortia recorded the highest seed yield (S_8-1081.50 kg ha^{-1}), whereas control without micro nutrient application (S_1) recorded the lowest pod yield of 489.66 kg ha^{-1}, which is on par with the foliar application of $NiCl_2$ -@5 ppm (S_4–542.87 kg ha^{-1}). The treatment that received the foliar application of consortia (S_8) recorded 120.86 per cent higher seed yield over control. In the present study, the higher seed yield with the foliar application of consortia might be due to higher net photosynthetic rate, higher capsule number, seed number, capsule weight and increased nutrient uptake. These results are coinciding with the findings of Gheshlaghi *et al.* (2019) who reported significantly higher seed yields with the complete irrigation and zinc foliar spray in soybean, which clearly explains the essential role of zinc in the plant, that is involved in the biosynthesis of growth hormones, such as auxin, which can produce more plant cells and there by more dry matter and store them in seeds (Devlin and Withan 1983). Similar increase in seed yield by 5 per cent in plants applied with zinc was reported in sesame (Shehu, 2014). In the present study, sesame plants with foliar application of consortia exhibited superior performance and improved the seed yield of sesame both under irrigated as well as under drought stress conditions.

CONCLUSIONS

In the present study, the effect of foliar application of micro nutrients were used to study the yield and yield attributes of sesame crop. Among the treatments foliar application of consortia *i.e.*, $ZnSO_4$ @3000ppm +H_3BO_3 @2000ppm +$NiCl_2$ @5 ppm+ $FeSO_4$ @3 ppm+ Na_2MoO_4 @0.5ppm and $ZnSO_4$ @3000ppm +H_3BO_3 @2000ppm showed better performance and improve the yield of sesame under water stress conditions during *rabi* season, 2022-23.

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Conflict of Interest. None.

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