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ZINC AND BORON MICRONUTRIENT FERTILIZATION ON THE GROWTH AND PHYSIOLOGICAL ATTRIBUTES OF SUNFLOWER IN RICE-SUNFLOWER CROPPING SEQUENCE

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Abstract

A field experiment was conducted at Experimental Farm, Annamalai University, Annamalainagar, Tamilnadu during summer season of 2014-15 to study the growth and physiological attributes of sunflower as influenced by soil and foliar fertilization of Zn and B. The experiment comprised of 12 treatment combinations which includes recommend dose of fertilizer (RDF) as control and RDF along with Zn and B soil and foliar fertilization at different stages of crop growth. From the experimental result, it could be concluded that soil application of micronutrients $ZnSO_4$ 25kg ha^{-1}, borax 5kg ha^{-1} and foliar fertilization of $ZnSO_4$ at the rate of 0.5 percent at star bud stage and borax 0.2 percent at ray floret stage was the optimal agronomic micronutrient management practice for obtaining higher values of growth attributes *viz*., plant height, days to fifty percent flowering, dry matter production, leaf area index and crop growth rate.

Key words: Boron, crop growth rate, leaf area index, micronutrient deficiency, zinc

Introduction

Sunflower (*Helianthus annuus* L.) is an important oil seed crop and has been considered as a promising alternative crop for traditional farming systems, particularly in the semi-arid regions. In world, sunflower is cultivated on an area of 27.29 million ha with an annual production and productivity of 49.56 million tonnes and 1820 kg ha^{-1}, respectively (NSA, 2019). In India, it is cultivated over an area of about 0.39 million ha with a production of 0.34 million tonnes and productivity of 842 kg ha^{-1} (USDA, 2018). In Tamil Nadu, sunflower cultivation has gained importance for the past two decades and currently 0.09 lakh ha area of land are under cultivation with an annual production of 0.113 lakh tonnes and the productivity of 1255 kg ha^{-1}.

Sunflower offers attractive price for the produce and the economics of the crop is significantly profitable compared to other crops in similar maturity groups. However, with a possible introduction and increase in acreage, as sunflower/gingelly/greengram-rice- sunflower /blackgram/maize/cotton cropping sequence in coastal zones of Tamil Nadu, and cultivation is probably on soils where salinity problems already exist or may develop from the use of saline irrigation water during critical periods of growth. It means that initial/latter stages, crops received good quality irrigation water, but other times the famers are intend to use saline ground water during the critical stages, especially during summer and *Kharif* seasons. Growing sunflower under degraded environments will lead to proper management practices soil salinity threatens the permanence of irrigated lands. Though the land/ irrigation water is saline, farmers use same methods of cultivation that are being used for fertile and productive lands. Use of poor quality water for irrigation (saline) during critical stages of crop may causes nutrient imbalance in the root zone and cause physiological drought are the major constraint for low productivity of crops (Rex Immanuel *et al*., 2018; Rex Immanuel and Ganapathy, 2019). It can be alleviated by using proper micronutrient fertilization. Micronutrients fertilization improves the crop quality and increases resistance in plants against biotic and abiotic stresses.

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Micronutrients are considered as trace nutrients which play a vital role on the plants growth and development and have a major contribution due to their necessity to enhance the growth and development of the crops under stress/degraded soil situations. Micronutrients are defined substances that are crucial for crop growth; however, they are used in lower amounts as compared to macronutrients such as N, P and K. Although soils may contain significant quantity of micronutrients, their accessibility to plants could be regulated, under the influence of different factors such as pH, competing cations, anions, organic matter and soil microbiology (Sarkar *et al*., 2007). The response of plants to the fertilization of micronutrients varies between species and cultivars and also depends upon the plant's penology, the physiological status and the environment in which the plant is growing (Huang *et al.*, 2008). Crop hybrids gave more encouraging response as compared to the variety and their levels of micronutrient response were different from each other (Kanwal *et al*., 2010). Micronutrients such as Zn and B can be important role at nutrition of oil seed crops (Khoshgoftarmanesh *et al.,* 2010).

The plant species and phenological stage have critical effects on the mobility of all elements but these are particularly important for the intermediate or conditionally mobile ones such as Zn and B (species dependent). In particular the mobility of micronutrients within plants is an important characteristic that determines plant growth and yield under conditions of limited nutrient availability (Marschner, 2012). Zn deficiency in Indian soils is expected to increase from 42 percent in 1970 to 63 percent by 2025 due to continuous depletion of soil fertility (Salwa *et al*., 2011; Singh, 2011). Globally, B deficiency has been recognized as the second most important micronutrient constraint in crops after Zn (Ahmad *et al*., 2014). Fernandez and Brown (2013) suggested that even a relatively small transport of foliar nutrients out of treated leaves and tissues may have a short-term, critical benefit to the plant. With the above background, the present study was planned to study the effect of individual and integrated applications of micronutrients Zn and B on sunflower growth and physiological attributes.

Materials and Methods

The field experiment was conducted in the field number GL 2 at the Experimental Farm, Department of Agronomy, Annamalai University, Annamalai Nagar, Tamil Nadu. The Experimental Farm is situated at 11°24' N latitude and 79°44' E longitude and at an altitude of +5.79 m above MSL (mean sea level) and 10 kms away from the Bay of Bengal. Field experiment was conducted during February to May 2014-15. During crop season the maximum temperature ranges from 29.2°C to 36.4°C with a mean of 32.8°C. The minimum temperature ranges from 20.8°C to 26.5°C with a mean of 23.6°C. The relative humidity ranges from 82 to 89 percent with a mean of 85 percent. The entire cropping period received the rainfall of 5.6 mm distributed over 6 rainy days. The soil is clay loam, moderately saline, low in organic carbon (0.42 %) and available nitrogen (212 kg ha^{-1}), medium in available phosphorus (20 kg ha^{-1}) and high in available potassium (279 kg ha^{-1}), low in available zinc (0.47 ppm) and boron (0.21 ppm). Rice crop was grown during previous season on the experimental site with normal package of practices.

The experiments were laid out in randomized block design with three replications. The details of the treatments consisted of T_1 – Control, T_2 - $ZnSO_4$ 25 kg ha^{-1} (Soil application (SA), T_3 - Borax 5 kg ha^{-1} (SA), T_4 - $ZnSO_4$ 0.5% foliar application at star bud stage (FA - SBS), T_5- Borax 0.2% foliar application at ray floret stage (FA at RFS), T_6-$ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA), T_7 - $ZnSO_4$ 25 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_8 - $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_9 - Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_{10} - Borax 5 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_{11} - $ZnSO_4$ 0.5% (FA - SBS) + Borax 0.2 % (FA - RFS) and T_{12} - $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS + Borax 0.2 % FA at RFS.

The sunflower hybrid 'Sun-bred' was chosen for the study. A recommended fertilizer schedule of hybrid sunflower *viz.,* 60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1} was adopted. N, P_2O_5 and K_2O were supplied through urea, single superphosphate and muriate of potash, respectively. As per treatment schedule, both zinc and boron were supplied from their respective sources and specific doses mentioned in the treatments by calculating the quantity based on the size of the plots. Zinc sulphate ($ZnSO_4$) was used as the source of zinc (containing 36% Zn), whereas borax (containing 11% boron) was used as the source of boron. In without foliar fertilization of micronutrients plots, same quantity of water was sprinkled over the foliage. Standard package of practices were followed as per the recommendation.

Establishment percentage was computed by recording total number of sunflower plants established against number of seeds sown in each plot on 10^{th} days after sowing (DAS). Seedling vigour index was computed at 15 DAS using the following procedure suggested by Abdul-Baki and Anderson (1973). The height of the plant from the ground level to the tip of top most apical bud were measured at physiological maturity stage and expressed in cm. Number of days taken for fifty per cent of the plant population to flowering from the date of sowing in each plot was recorded as number of days taken for fifty per cent flowering. Estimation of dry matter was recorded at star bud stage (SBS), ray floret stage (RFS) and at harvest stage of the crop and expressed in kg ha^{-1}. Leaf area was measured at ray floret stage and computed as LAI following the method suggested by Prabhakar and Jaganath (1973). The crop growth rate (CGR) during the growth period *viz*., germination to star bud stage (0 – SBS), star bud stage to ray floret stage (SBS – RFS) and ray floret stage to physiological maturity stage (RFS – PMS) were calculated as the method suggested by Watson (1958) and expressed in mg m^{-2} day^{-1}. The data on observations and characters studied were statistically analyzed by adopting the procedure of Panse and Sukhastme (1978) and for the results that were significant, the critical differences were calculated at 5 per cent probability level to draw statistical conclusion.

Results and Discussion

Growth attributes

Application of $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 percent FA at SBS + Borax 0.2 percent FA at RFS (T_{12}) significantly registered the higher vigour index of 1466.65. However, this treatment was on par with the treatment T_6 ($ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA). While, the establishment per cent of sunflower was not significant. The maximum significant plant height of 158.23 cm, minimum number of days to fifty percent flowering of 55.63 days and highest DMP of 6115.18 kg ha^{-1} were recorded under treatment T_{12} ($ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 per cent FA at SBS + Borax 0.2 percent FA at RFS.

Addition of micronutrients Zn and B along with other macronutrients under micronutrient deficit soil is a general trend to enhanced vigour of seedlings in the early stages. Thus, application of adequate micronutrients in the initial stages itself led to balanced soil macro and micro nutrient status which enhanced the available nutrient element concentrations in the rhizosphere soil. Its availability initially enhanced the root growth and improved acquisition of nutrients from the soil and enhances the shoot length which ultimately conferred with higher vigour of seedlings. The reports of following findings supported the present study. The function of zinc in soil nutrition is of special significance due to its role in sustaining membrane integrity of root cells (Welch, 1995). El-Shintinawy (1999) and Tariq and Mott (2007) reported that boron deficiency induced a remarkable inhibition in sunflower plant growth, as shown by a reduction in dry mass of roots and shoots of plants. Similarly, sunflower roots are also affected by low supply of B and results obtained by Dugger (1983) indicated that sunflower plants stop their growth in < 6 hrs after the removal of B from the growth medium. Ultimately the possible function of zinc in lowering the toxic influences of excessive boron also reported by Moore *et al.,* (1983). This study also supports the balancing of excessive micronutrients in the rhizosphere. In the present study soil application of micronutrients Zn and B involved in balanced availability and transport of macro nutrients *viz*., N, P and K which in turn enhances the development of wealthier root system followed by shoot growth during early stages and improved the vigour index of sunflower crop confirmed by treatment T_{12} and T_6 ($ZnSO_4$ at 25 kg ha^{-1} and

Table 1: Growth attributes of sunflower as influenced by Zn and B fertilization.

Treatments	Establishment percentage	Vigour Index	Plant height (cm)	Days to 50% flowering	DMP (kg ha^{-1})
T_1	84.22	1128.60	112.10	64.15	1980
T_2	86.18	1274.29	124.21	62.75	3791
T_3	85.10	1238.32	122.45	63.60	3684
T_4	88.35	1160.18	129.44	61.32	4461
T_5	87.26	1182.55	127.30	62.00	4363
T_6	94.77	1435.39	151.77	56.67	5994
T_7	92.26	1368.43	140.86	58.05	5662
T_8	93.72	1402.92	145.66	57.28	5811
T_9	91.58	1345.97	139.50	58.74	5560
T_{10}	89.43	1310.31	134.19	59.60	4977
T_{11}	90.50	1215.41	132.50	60.35	5328
T_{12}	95.86	1466.65	158.23	55.63	6115
SEd	0.53	18.50	2.65	0.33	54
CD(p=0.05)	NS	37.02	5.28	0.72	112

[T_1 –Control (60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}), T_2 – NPK + $ZnSO_4$ 25 kg ha^{-1} (SA), T_3 – NPK + Borax 5 kg ha^{-1} (SA) T_4 - NPK + $ZnSO_4$ 0.5 % foliar application at star bud stage (FA - SBS), T_5 - NPK + Borax 0.2 % foliar application at ray floret stage (FA at RFS), T_6 - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA), T_7 - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_8 - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_9 - NPK + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_{10} - NPK + Borax 5 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_{11} - NPK + $ZnSO_4$ 0.5% (FA - SBS) + Borax 0.2 % (FA - RFS) and T_{12} - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS + Borax 0.2 % FA at RFS] borax at 5 kg ha^{-1}) over control (T_1). From the results it should be know that soil application of micronutrients Zn and B are very essential to enhance the vigour index of hybrid sunflower crop especially grown under stressed (salinity/drought/poor irrigation water) soils.

Plant height is an extremely important trait because it affects the stability of the plant *i.e.* the resistance to lodging. The early stages of crop growth were vigorous and needed more sustained nutrients for cell division. The beneficial effect of Zn on plant height due to its essential for synthesis of proteins and auxin in plants and it activates enzymes such as proteinase and peptidases. Trehan and Sharma (2000) found that relative shoot dry matter yield without zinc expressed on percentage of yield with adequate zinc was 130 percent for sunflower, indicating that sunflower was most zinc efficient. In this concern, increasing Zn fertilization increased plant height was reported by Marie and Howarth (2009) and Hadi *et al*., (2014). Boron also involved in source of plant processes such as cell wall synthesis, lignification, meristematic tissue cell division, leaf bud formation, cell wall structure integrity, sugar and hydrocarbon metabolism and their transport, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, cytokinin production and transfer, phenol metabolism, *etc*. Optimal availability of B micronutrient also increased the root growth of sunflower crop which helps to extraction of more nutrients from the rhizosphere soil. The results are agree with the findings of Deperon *et al.,* (2007) and Tahir *et al*., (2014).

Biological yield is the total biomass produced (DMP) by crop utilizing the resources available at the time. The data concerning biological yield revealed that DMP was significantly affected by micronutrient fertilization. The sustained availability of micronutrients till the maturity stage due to the treatment would have enhanced better source-sink relationship which eventually contributed to larger quantity of total DMP of sunflower. In cultivated crops, nutrient demand is at its climax during the maximum (grand) phase of vegetative development. During these phase as much as 40 per cent of total nutrient accumulation can be acquired over a 10 day period (Siddiqui *et al.,* 2009). Foliar fertilization of Zn and B during the period of highest nutrient demand under the premise that soil supply and root uptake may be inadequate to meet demands even with adequate soil applied fertilizer. The cumulative effect of both soil and foliar applied Zn and B enhancing the metabolic process and production of DMP are corroborate with the findings of Patil *et al.,* (2006); Siddiqui *et al*., (2009) and Hadi *et al*., (2014).

Table 2: Physiological attributes of sunflower as influenced by Zn and B fertilization.

Treatments	Leaf area index at 50 % flowering	Crop growth rate (CGR) mg m^{-2} day^{-1}		
		0 - SBS (43 days)	SBS - RFS (14 days)	RFS – PMS (32 days)
T_1	1.50	6.95	3.46	7.48
T_2	3.28	8.20	4.90	8.27
T_3	3.13	7.81	4.60	7.94
T_4	4.38	7.15	3.78	9.00
T_5	4.00	7.19	4.05	8.71
T_6	5.42	10.12	6.51	11.65
T_7	4.89	9.32	5.88	10.73
T_8	5.22	9.71	6.19	11.20
T_9	4.75	8.98	5.56	10.36
T_{10}	3.85	8.58	5.22	9.44
T_{11}	4.56	7.39	4.34	9.88
T_{12}	5.63	10.52	6.94	12.10
SEd	0.07	0.16	0.12	0.18
CD(p=0.05)	0.16	0.36	0.28	0.41

[T_1 –Control (60 kg N, 90 kg P_2O_5 and 60 kg K_2O ha^{-1}), T_2 – NPK + $ZnSO_4$ 25 kg ha^{-1} (SA), T_3 – NPK + Borax 5 kg ha^{-1} (SA) T_4 - NPK + $ZnSO_4$ 0.5 % foliar application at star bud stage (FA - SBS), T_5 - NPK + Borax 0.2 % foliar application at ray floret stage (FA at RFS), T_6 - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA), T_7 - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_8 - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_9 - NPK + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS, T_{10} - NPK + Borax 5 kg ha^{-1} (SA) + Borax 0.2 % FA at RFS, T_{11} - NPK + $ZnSO_4$ 0.5% (FA- SBS) + Borax 0.2 % (FA - RFS) and T_{12} - NPK + $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 % FA at SBS + Borax 0.2 % FA at RFS; SBS – star bud stage, RFS – ray floret stage, PMS –physiological maturity stage]

Physiological attributes

The observations recorded on physiological attributes of the sunflower crop are given in table 2. The treatment T_{12} ($ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 per cent FA at SBS + Borax 0.2 percent FA at RFS) significantly recorded the higher leaf area index of 5.63 at 50 percent flowering stage of sunflower crop. The CGR was also markedly influenced by the different micronutrient treatments. The higher CGR value was registered in $ZnSO_4$ 25 kg ha^{-1} (SA) + Borax 5 kg ha^{-1} (SA) + $ZnSO_4$ 0.5 per cent FA at SBS + Borax 0.2 per cent FA at RFS treatment (T_{12}). It recorded the CGR values of 10.52, 6.94 and 12.10 mg m^{-2} day^{-1} in germination to star bud stage (0 – SBS), star bud stage to ray floret stage (SBS – RFS) and ray floret stage to physiological maturity stage (RFS – PMS), respectively.

Micronutrients like Zn and B are known to influence the plant growth more profoundly by indirect ways than direct participation in physiological activities. Its availability enabled the sunflower crop to utilize the soil available nutrients to the maximum extent of growth during vegetative stage. Higher the plant height, greater the length of stem and longer stem will possess more numbers of nodes which in turn will result in more number of leaves and finally leaf area. Leaf area is an important part of the plant responsible for interception and conversion of solar energy. Physiological factors and favourable ecological conditions determine the degree of elongation of the healthy internodes and its summation decides the maximum plant height, better LAI and CGR of sunflower. The present results are in agreement with the findings of Khoshgoftarmanesh *et al*., (2010) and Rashid *et al.,* (2012).

The number of leaves and the leaf area were increased by addition of these Zn and B micronutrients which led to increase in growth. Obviously, the higher number of leaves will be reflected in case of LAI. Due to significantly higher leaf area and LAI it might have contributed to higher net photosynthesizing area. Higher photosynthesizing area facilitated maximum amount of photosynthesis which resulted in significantly maximum CGR. Less response of sunflower to other Zn and B micronutrient management treatments and control could be attributed to imbalanced macronutrient availability to sunflower crop due to low status of micronutrients *viz*., Zn and B. It was confirmed from the performance of growth attributes recorded in control treatment (T_1), which receives 100 percent macronutrients such as N, P and K failed to exhibits its full potential. Among the micronutrients, Zn and B deficiency is common, particularly in high pH soils and reduces net photosynthesis, increasing chlorosis and severely affected the physiological attributes of sunflower.

Conclusion

In view of the above observations, it can be concluded that soil application of micronutrients $ZnSO_4$ 25 kg ha^{-1}, borax 5 kg ha^{-1} along with foliar fertilization of $ZnSO_4$ at the rate of 0.5 percent at star bud stage (SBS) and borax 0.2 percent at ray floret stage (RFS) was the optimal agronomic micronutrient management dose for obtaining the maximum vigour index, higher DMP, LAI and RGR of hybrid sunflower crop in rice-sunflower cropping sequence.

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