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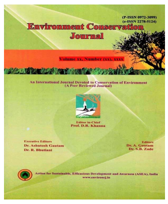

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Nutritional effect of zinc and boron on growth, yield and oil content of hybrid sunflower (*Helianthus annuus* L.)

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ABSTRACT

The experiment was conducted to assess the impactofZn and B application on sunflower growth, yield and oil content in sub-tropical condition. The experiment was laid out in randomized complete block design (RCBD) with twelve treatmentsand replicated thrice. The treatments comprised *viz*; T_1: Without fertilizers (absolute control), T_2: RDF ($N_{80}P_{40}K_{40}$), T_3: $N_{80}P_{40}K_{40}Zn_{0.5\%}$, T_4: $N_{80}P_{40}K_{40}Zn_4$, T_5: $N_{80}P_{40}K_{40}B_{0.2\%}$, T_6: $N_{80}P_{40}K_{40}B_2$, T_7:$N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$,$T_8$: $N_{80}P_{40}K_{40}Zn_4B_2$, T_9:$N_{80}P_{40}K_{40}Zn_4Zn_{0.5\%}$, T_{10}: $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$, T_{11}: $N_{80}P_{40}K_{40}B_2B_{0.2\%}$, T_{12}: $N_{80}P_{40}K_{40}B_2Zn_{0.5\%}$.From the experimental results recorded it can be concluded that the growth and yield components of the tested crop were significantly influenced by the application of micronutrients as compared to the control (without fertilizer) and recommended dose of fertilizer alone. Among the treatmentsapplication of $N_{80}P_{40}K_{40}Zn_4B_2$foundhigher diameter of capitulum (17.72 cm), number of seeds per capitulum (763), seed weight per capitulum(48.98 g), seed yield (2563 kg/ha) and oil yield (1097 kg/ha) of hybrid sunflower (variety KBSH 78) accounting 35.49%,43.25%, 26.66%, 46.50% and 51.32% more than control.

Introduction

Sunflower (*Helianthus annuus* L.) is the fourth most important (after groundnut, mustard and soybean) non-conventional oilseed crop cultivated in India. Recently, sunflower became very popular because of its short duration, high oil quality, photo-insensitivity, drought tolerance, and wider adaptability to a diversity of cropping patterns.Its oil is abundant in polyunsaturated fatty acids (60 %), linoleic and oleic acid of 72.5% and 16.0 % respectively. Seed has greater oil content (35-48 %), which helps to manage blood cholesterol in human (Patra *et al.*, 2013). As the protein content of oil cake is rich in quality protein (40-44%), it can be used as cattle and poultry feed.Sunflower is currently grown in0.26 million hectares in India, with a production of and average productivity of 0.22 million tonnes and 826 kg/ ha respectively. It is grown in 0.01 million hectares in West Bengal, with a production of 0.01 million tonnes and productivity of 952 kg/ ha (Agricultural Statistics at a Glance, DES, GOI, 2020). India is significantly reliant on imports to meet its edible oil demand,

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and the country is the world's leading importer of vegetable oils followed by China and the United States (Annual Report, DF& PD 2020-21). Imports of edible oil have doubled the domestic production (all primary and secondary sources), placing the country under severe economic pressure. Under such conditions, increasing oilseed crop production and productivity is essential in order to close the gap between current demand and supply via advancing production technology. Sunflower, a premium crop, is still in its early phases of development, but it appears to be the most essential oilseed crop for combating the oil issue in the future.

Micronutrient deficiency in Indian soil is progressively emerging and becoming a severe constraint to sustainable agriculture. Deficiency of micronutrient in Indian soil has been recorded with respect to Zn (36.50 %), Fe (12.8 %), Cu (4.20 %), Mn (7.10 %), and B (23.4 %), while West Bengal soil has a deficiency of Zn (14.42 %), Fe (0.03 %), Cu (1.76 %), Mn (0.98 %), and B (37.05 %) (Shukla *et al.*, 2018).This is aggravated by agriculture intensification, followed by the use of high-analysis fertilizer. Furthermore, cultivation is mostly restricted to small and marginal farmers with low socio-economic condition. Nevertheless in the current exploitive agriculture, large-scale production improvements have also been observed with the application of micronutrients in combination with NPK (Rego *et al.*, 2007).

Boron plays a vital role in hormonal development, cell division, fruit and seed setting, sugar translocation of crops (Ahmad *et al.*, 2021). Deficiency of B in sunflower cause pollen tube deformation resulting in increased empty seeds in sunflower on the other hand, zinc is essential for a variety of physiological and metabolic activities in plants. Zinc deficiency diminishes net photosynthesis, induces chlorosis and necrotic patches on the leaves, and significantly reduce yield of the crop (Alloway, 2008). Hence the sustainable solution is application of sufficient and balanced nutrient for proper plant growth and biomass production in sunflower (Banerjee *et al.*, 2014). Application of micronutrients like zincand boron and iron through broadcasting and foliar application is known to enhancethe yield, yield components of oilseeds crop (Alloway, 2008). The combinedapplication of Zn and B was found to be beneficial in increasing chlorophyll content, nutrient uptake, yield and oil content in sunflower(Gitte *et al.*, 2005; Rex Immanuel *et al.*, 2020). Foliar application is better than soil application as rapid translocation of nutrients to leaf and seed take place, but foliar spray does not completely replace soil-applied fertilizer; however, it can only improve nutrientuptake. So it is the efficiency of soil-applied nutrients that ultimately brings increased crop production (Kannan, 2010). With this perspective, the experiment was mainly focused on micronutrient (Zn and B) management in sunflower, either soil applied, foliar spray or in combination during *rabi* season in irrigated conditions.

Material and Methods

The field experiment was laid out at farmer's field located in Panchkahania, Barajaguli, Nadia under sub humid and sub-tropical climatic conditions of West Bengalduring *rabi* season of 2020-21. Maximum and minimum temperature of the experimental area was fluctuated between 33.2^{0}C and 24.8^{0}C and 20.8^{0}C and 11.5^{0}Crespectively. Relative humidity prevailed between 96.5% and 41.27% during the period of experimentation.The soil of the experimental site was sandy loam in texture having pH 7.2, EC 0.46dS/m, medium organic carbon, 219.0 kg N/ha, 31.24kg P_2O_5/ha and 218.23kg K_2O/ha respectively.

The experiment was laid outin randomized complete block design (RCBD), with twelve treatment combinations andreplicated thrice. The treatments comprised *viz*; T_1: Without fertilizers (absolute control), T_2: RDF (80-40-40)NPK kg/ha ($N_{80}P_{40}K_{40}$), T_3 : RDF + Foliar Application(FA) of Zn @0.5% at 25 DAS ($N_{80}P_{40}K_{40}Zn_{0.5\%}$), T_4: RDF + Soil application (SA) of Zn @ 4 kg/ha ($N_{80}P_{40}K_{40}Zn_4$), T_5: RDF + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}B_{0.2\%}$), T_6: RDF + SA of B @ 2 kg/ha as basal($N_{80}P_{40}K_{40}B_2$), T_7: RDF +FA of Zn @ 0.5% at 25 DAS + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$), T_8: RDF + SA of Zn @ 4 kg/ha + B @ 2 kg/ha($N_{80}P_{40}K_{40}Zn_4B_2$), T_9 : RDF + SA of Zn @ 4 kg/ha + FA of Zn @0.5% at 25 DAS($N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$), T_{10} : RDF + SA of Zn @ 4 kg/ha + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$), T_{11} : RDF + SA of B @

2 kg/ha + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}B_2B_{0.2\%}$), T_{12} : RDF + SA of B @ 2 kg/ha + FA of Zn @0.5% at 25 DAS($N_{80}P_{40}K_{40}B_2Zn_{0.5\%}$). All phosphorus and potassium fertilizers were added to the soil at the time of sowing in each plot according to the recommended dose. However, nitrogen fertilizer was applied in two splits i.e, 50% each at the time of sowing and at 30 days after sowing (DAS). The hybrid seed 'KBSH 78' was sown on 21st November, 2020, by maintaining a spacing of 60cm × 30cm. After harvesting, seeds were manually separated from capitulum and air-dried. Weight of seeds was recorded by discarding the border plantsand then converted into kg/ha. And seed index represented the weight of 100 sunflower seeds. The plants (without capitulum) were sun-dried and weighed to get stem and husk yield and finally presented in kg/ha.

Oil content determination was done by following the standard procedure (AOAC, 2005). Oil yield could be determined by multiplying their concentrations (%) with the seed yield (kg/ha) divided by 100.

The final recorded data were subjected to analysis of variance (ANOVA) as randomized complete block design(Gomez and Gomez, 1984). The significant difference for sources of variance was tested by error mean square by Fisher Snedecor's 'F' test at probability level of 0.05. For comparison of 'F' values and computation of critical difference (CD) at 5% level of significance, Fisher and Yates' tables were used.

Results and Discussion

Growth attributes

The experimental results postulated that the application of primary nutrients and micronutrients in various combination showed pronounced effect on growth of hybrid sunflower (Table 1). Significantly different plant height was observed at all the stages of growth except at early growth stage i.e. 30 DAS. Application of $N_{80}P_{40}K_{40}Zn_4B_2$ recorded maximum plant height at harvest (170.4 cm). However, accounting 12.33 % more than RDF treatment and remained at par with $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$ (168.7 cm)and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$(165.1 cm) and significantly different from control. The least plant height was recorded with absolute control (141.0cm).This could be attributed to increase photosynthetic and metabolic activity, which is responsible for cell division and cell elongation thatresulted in increases plant height.Baloch *et al.* (2015) and Elayaraja *et al.* (2019) also found a positive response between soils applied micronutrients and plant height.Longer stems (higher plant height) had more nodes, which resulted in more number of leaves as the plant grows taller(Ramulu *et al.,* 2011). In the present study significantly higher LAI was obtained at 60 DAS and declined gradually, as the crop progressed towards physiological maturity. The maximum value of LAI was obtained with the application of $N_{80}P_{40}K_{40}Zn_4B_2$ at 60DAS (4.85) which remain at par with $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$ (4.73)and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$ (4.59) and the minimum was observed in absolute control plot (3.52). Dry matter accumulation (DMA) increased progressively with the advancement in growth and continued until maturity in all the treatments. The DMA was found to be higher with $N_{80}P_{40}K_{40}Zn_4B_2$all throughout the crop growth stage and finally reached at 1458.1 g/m^2 during harvest which was not significantly different from $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$ (1432.2 g/m^2) and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$ (1395.6 g/m^2) accounting 35.06% more than RDF.More leaf area and LAI of sunflower plants realized with this treatment might have allowed more solar energy to be captured over longer periods of time, resulting in more photosynthesis and higher total dry matter (Ravikumar *et al.,* 2021). The availability of micronutrients due to the treatment from planting to maturity stage would have improved the source-sink relationship, resulted in a larger quantity of total DMA of sunflower(Alipatra *et al*., 2019).

The different micronutrient treatmentsalso influenced crop growth rate. The highest CGR value of 14.99 and 25.66 g/m^2/day was recorded in $N_{80}P_{40}K_{40}Zn_4B_2$ between 30-60DAS and 60DAS-harvest, respectively and it was closely followed by the treatments with $N_{80}P_{40}K_{40}Zn_4Zn_{0.5\%}$ and $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$. Micronutrients, zinc and boron in particular, are known to have profound influence on the plant growth by indirect ways than direct participation in physiological activities (Rex Immanuel *et al*., 2020). Hence, their availability might have induced the ability of sunflower crop to utilize the soil available nutrients to the maximum extent during vegetative stage. Furthermore, Banerjee *et al.* (2014) opined that the degree of

Table 1:Growth attributes of hybrid sunflower as influenced by the application of zinc and boron during *rabi 2020-21*

Treatments	Plant height (cm)			LAI			DMA (g/m^2)			CGR (g/m^2/day)	
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30-60 DAS	60-108 DAS
Absolute Control	11.6	48.4	141.0	1.39	3.52	1.57	13.0	365.3	1064.5	11.74	17.51
$N_{80}P_{40}K_{40}$ (RDF)	11.1	55.4	151.7	1.52	3.68	1.96	13.4	374.1	1079.6	12.02	17.64
$N_{80}P_{40}K_{40}Zn_{0.5\%}$	11.0	55.7	155.0	1.55	3.72	1.70	13.4	377.7	1113.5	12.14	18.80
$N_{80}P_{40}K_{40}Zn_{4}$	10.9	50.9	158.7	1.51	3.80	1.95	14.5	404.6	1173.3	13.00	19.38
$N_{80}P_{40}K_{40}B_{0.2\%}$	10.7	51.3	156.6	1.62	3.78	1.84	13.7	381.3	1122.9	12.26	19.25
$N_{80}P_{40}K_{40}B_{2}$	10.6	51.9	160.8	1.68	3.86	2.18	14.7	411.2	1273.2	13.22	21.97
$N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$	11.3	55.5	161.7	1.72	3.97	2.34	16.3	416.4	1312.1	13.68	22.87
$N_{80}P_{40}K_{40}Zn_{4}B_{2}$	12.0	62.7	170.4	1.92	4.85	2.90	19.0	475.8	1458.1	14.99	25.66
$N_{80}P_{40}K_{40}$ $Zn_{4}Zn_{0.5\%}$	11.5	58.8	165.1	1.83	4.59	2.68	18.1	446.6	1395.6	14.28	24.58
$N_{80}P_{40}K_{40}Zn_{4}B_{0.2\%}$	11.5	62.2	168.7	1.87	4.73	2.84	18.6	467.7	1432.2	14.77	25.11
$N_{80}P_{40}K_{40}B_{2}B_{0.2\%}$	11.1	55.7	162.0	1.71	3.78	2.23	16.0	414.9	1279.0	13.56	22.60
$N_{80}P_{40}K_{40}B_{2}Zn_{0.5\%}$	11.2	56.5	160.4	1.77	4.36	2.43	17.9	442.9	1374.7	13.99	24.29
SEm ±	0.3	2.0	2.55	0.04	0.12	0.08	0.9	10.27	26.74	0.38	1.05
CD (P=0.05)	NS	6.1	7.86	0.13	0.37	0.26	2.9	31.66	82.39	1.16	3.23

RDF- Recommended dose of fertilizer; Subscript digits signify respective dose of N, P, K, Zn and B in Kg /ha
***NS- Non-significant; LAI- Leaf Area Index; DMA- Dry Matter Accumulation; CGR- Crop Growth Rate; DAS – Days After Sowing**

Table 2: Yield components, seed yield, oil content and oil yield of hybrid sunflower as influenced by the application of zinc and boron during *rabi* 2020-21

Treatments	Capitulum diameter (cm)	Number of seeds/capitulum	Seed weight/capitulum(g)	Seed index(g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
Absolute Control	11.43	433	34.45	4.95	1371	38.96	534
$N_{80}P_{40}K_{40}$ (RDF)	14.06	518	38.47	5.14	1806	40.14	725
$N_{80}P_{40}K_{40}Zn_{0.5\%}$	14.87	536	40.40	5.26	1951	41.53	810
$N_{80}P_{40}K_{40}Zn_{4}$	15.10	582	41.98	5.37	2118	41.29	874
$N_{80}P_{40}K_{40}B_{0.2\%}$	14.94	533	40.76	5.30	2068	41.45	856
$N_{80}P_{40}K_{40}B_{2}$	15.42	613	42.86	5.36	2194	41.18	904
$N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$	16.17	626	46.19	5.45	2297	41.95	964
$N_{80}P_{40}K_{40}Zn_{4}B_{2}$	17.72	763	48.98	6.16	2563	42.78	1097
$N_{80}P_{40}K_{40}$ $Zn_{4}Zn_{0.5\%}$	16.33	665	46.38	5.78	2374	42.42	1008
$N_{80}P_{40}K_{40}Zn_{4}B_{0.2\%}$	16.88	739	47.90	6.08	2427	42.57	1034
$N_{80}P_{40}K_{40}B_{2}B_{0.2\%}$	15.77	622	46.10	5.40	2251	42.20	950
$N_{80}P_{40}K_{40}B_{2}Zn_{0.5\%}$	16.25	657	46.27	5.71	2321	42.12	977
SEm ±	0.46	35.5	0.85	0.13	67.09	0.31	42
CD(P=0.05)	1.42	100.18	2.62	0.39	206.72	0.97	128

Table 3: Pearson's correlation co-efficient showing pair-wise association of different traits assessed for hybrid sunflower grown during *rabi* 2020-21

Parameters	PH 30 DAS	PH 60 DAS	PH 108 DAS	LAI 30 DAS	LAI 60 DAS	LAI 108 DAS	DMA 30 DAS	DMA 60 DAS	DMA 108 DAS	CGR 30-60 DAS	CGR 60-108 DAS	CD	NSC	SWC	SI	SY	OC	OY
PH 30 DAS	1.000																	
PH 60 DAS	0.600*																	
PH108DAS	0.242^{NS}	0.798**																
LAI DAS	0.428^{NS}	0.860**	0.929**															
LAI DAS	0.622*	0.872**	0.823**	0.912**														
LAI 108 DAS	0.545^{NS}	0.870**	0.896**	0.957**	0.943**													
DMA 30DAS	0.596*	0.837**	0.850**	0.939**	0.946**	0.967**												
DMA 60DAS	0.543^{NS}	0.829**	0.894**	0.938**	0.955**	0.972**	0.981**											
DMA108 DAS	0.498^{NS}	0.796**	0.889**	0.957**	0.916**	0.966**	0.980**	0.981**										
CGR30-60 DAS	0.518^{NS}	0.813**	0.913**	0.945**	0.921**	0.974**	0.979**	0.991**	0.990**									
CGR60-108 DAS	0.469^{NS}	0.786**	0.886**	0.965**	0.896**	0.951**	0.972**	0.965**	0.995**	0.978**								
CD	0.225^{NS}	0.808**	0.980**	0.923**	0.807**	0.869**	0.841**	0.868**	0.870**	0.886**	0.872**							
NSC	0.427^{NS}	0.857**	0.962**	0.956**	0.913**	0.962**	0.941**	0.975**	0.960**	0.977**	0.948**	0.945**						
SWC	0.332^{NS}	0.799**	0.961**	0.947**	0.823**	0.913**	0.917**	0.919**	0.941**	0.950**	0.948**	0.964**	0.961**					
SI	0.547^{NS}	0.884**	0.900**	0.935**	0.978**	0.949**	0.947**	0.974**	0.931**	0.950**	0.914**	0.883**	0.965**	0.891**				
SY	0.194^{NS}	0.752**	0.985**	0.926**	0.800**	0.874**	0.853**	0.880**	0.891**	0.904**	0.896**	0.990**	0.945**	0.974**	0.874**			
OC	0.206^{NS}	0.774**	0.949**	0.897**	0.766**	0.806**	0.820**	0.826**	0.838**	0.851**	0.856**	0.965**	0.894**	0.953**	0.847**	0.963**		
OY	0.222^{NS}	0.768**	0.985**	0.934**	0.812**	0.880**	0.865**	0.888**	0.899**	0.912**	0.904**	0.991**	0.950**	0.980**	0.885**	0.999**	0.972**	

Notes: DAS= Days After Sowing; PH = Plant height in cm, LAI = Leaf area index, DMA = Total dry matter accumulation in g/m^2, CGR= Crop growth rate in g/m^2/day, CD = Capitulum diameter at harvest in cm, NSC = Number of seeds/capitulum, SWC= Seed weight/ capitulum in g, SI = Seed index in g, SY = Seed yield in kg/ha, OC= Oil content in (%) and OY= Oil yield in kg/ha, NS= non-significant

***and ** represents significance at 5% and 1% levels respectively**

internode elongation is influenced by physiological parameters, favourable environmental conditions, and the time of fertiliser application, which exerts positive impacts on plant height, LAI, DMA and CGR of sunflower.

Yield components

Yield components of tested hybrid sunflower variety wererecorded and significantly higher capitulum diameter (17.72 cm), number of seeds/capitulum (763), seed weight/capitulum (48.98 g) and seed index (6.16 g) were found with the application of $N_{80}P_{40}K_{40}Zn_4B_2$ and it was statistically at par with $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$ and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$, accounting 35.5, 43.2, 29.7 and 19.6 % more than control respectively. This might be due to addition of micronutrients (zinc and boron) along with macronutrients (NPK) under micronutrient deficit condition that adds to seedling hardiness in the early stages. Thus, application of sufficient micronutrients in the initial stages might haveresulted in balanced soil macro and micronutrient status which improved nutrient availability in the rhizosphere soil (Rex Immanuel *et al.,* 2019). Besides, Zn and B plays a key function in boosting crop photosynthetic ability and participating in a number of enzymatic and other biochemical reactions, metabolism of carbohydrates, protein synthesis, chlorophyll synthesis (Patil *et al*., 2006) anther and pollen grain development (Krudnak *et al*., 2013).In present study also, partitioning of photosynthates from source to sink was better due to a balanced supply of these nutrients which ultimately resulted in higher yield attributing traits of hybrid sunflower. These results were corroborated with the findings of Shekhawat and Shivay (2008) and Sheoran *et al.,* (2018).Further Zn induced pollination by influencing pollen tube formation, that decided the number of seeds/capitulum and capitulum diameter which directly influence the seed yield (Alipatra *et al*., 2019). According to Ramulu *et al*. (2011), an increase ofcapitulum diameter by one centimetre would increase the number of seeds in sunflower by 75 to 100. Furthermore, there exists a direct relationship between seed yield and seed index, as the size of seed increased with increase in seed weight. The contribution of total number of seeds/capitulum to seed yield increases as the number of filled seeds/capitulum increases (Rex Immanuel *et al.,* 2020). A significant increase in seeds/capitulum with B application was observed due to induce flowering, pollen germination, and water balance between photosynthesis and respiration of the crop plant (Alipatra *et al.,* 2019). They further opined that B application increases the pollen- producing capacity, pollen viability, and seed setting, ultimately increases the seed index.

Seed yield, oil yield and oil content

Application of $N_{80}P_{40}K_{40}Zn_4B_2$ resulted in significantly higher seed yield (2563 kg/ha), oil content (42.78%) and oil yield (1097 kg/ha) accounting 46.5, 8.9 and 51.3% higher than control respectively. However, there was no significant difference in the yield components of tested variety with the applications of $N_{80}P_{40}K_{40}Zn_4B_2$, $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$ and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$ (Table 2 and Fig 1). An increase in seed yield is accounted for increase in yield components especially number of filled seed/capitulum, seed weight/capitulum and seed index, as observed in the present study also. Such response might be due to balanced supply of these nutrients that causes increased rate of photosynthesis and translocation of photosynthates to the site of storage organ ultimately resulted higher yield of sunflower (Ravikumar *et al.,* 2021). The seed oil content is an important parameter of sunflower. Oil content decided the oil yield and oil yields mirrored the response of seed yields being significantly increased due to the Zn and B fertilization (Sheoran *et al.,* 2018). The higher oil content and oil yield might be due to enzymatic activity in the formation of glucosides, glucosinolates and additionally sulphydril-linkage in biochemical reaction within the plant which helps in bio-synthesis of oil. These results are also in accordance with the earliest finding of Suryavanshi *et al.* (2015) and Sheoran *et al.* (2016). Furthermore, soil application of zinc and boron increases the fertilizer (NPK) use efficiency (Patil *et al*., 2006) thereby produces higher yield of quality sunflower seeds. Gitte *et al.* (2005) was in the view that combined application of Zn and B is more effective than Zn alone or B alone.

Correlation studies

In order to show how the growth and yield parameters were interacted with one another and with the yield of the hybrid sunflower, Pearsoncorrelation coefficients were determined

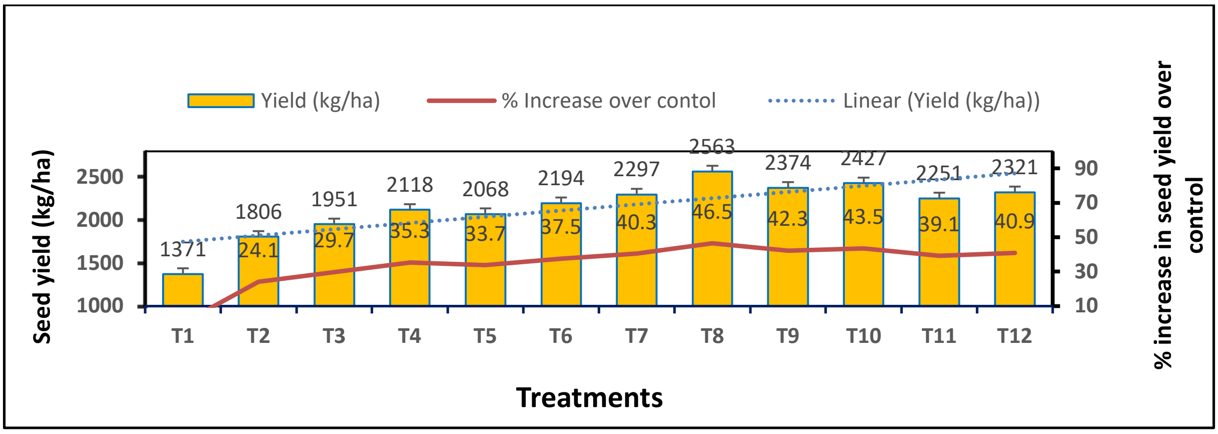

Figure1: Effect of Zn and B application on seed yield and percent increase in seed yield of hybrid sunflower over control

T_1 : (Without fertilizers) absolute control, T_2: $N_{80}P_{40}K_{40}$, T_3 : $N_{80}P_{40}K_{40}Zn_{0.5\%}$, T_4: $N_{80}P_{40}K_{40}Zn_4$, T_5: $N_{80}P_{40}K_{40}B_{0.2\%}$, T_6: $N_{80}P_{40}K_{40}B_2$, T_7: $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$, T_8: $N_{80}P_{40}K_{40}Zn_4B_2$, T_9 : $N_{80}P_{40}K_{40}Zn_4Zn_{0.5\%}$, T_{10} : $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$, T_{11} : $N_{80}P_{40}K_{40}B_2B_{0.2\%}$, T_{12} : $N_{80}P_{40}K_{40}B_2Zn_{0.5\%}$

(Table 3). The highly significant and favourable correlation between seed yield and LAI, DMA, capitulum diameter, seed weight per capitulum, number of seed per capitulum, and seed index (100-seed weight) was found in the current study concluded that adequate accumulation of photosynthates during vegetative phase and its efficient translocation to the storage organ site during reproductive phase, and ultimately supporting the crop for producing higher seed yield. The positive and highly significant relationship was found to exist between seed yield and oil content and oil yield which suggested that oil productivity is directly dependent on seed yield and oil content.

Conclusion

Micronutrients play different specific roles in the plant growth and development processes. The current experiment also clearly showed the favourable role of micronutrients especially Zn and B in augmenting sunflower production. Maximum plant height, leaf area index, dry matter accumulation, crop growth rate, yield components like capitulum diameter, number of seed/ capitulum, seed yield, oil yield etc. were found to be highest with the soil application of zinc and boron @ 4kg/ha and 2 kg/ha respectively. Hence their application in combination with RDF i.e. $N_{80}P_{40}K_{40}Zn_4B_2$kg/ha was identified as best treatment combination for higher productivity and profitability of sunflower production in alluvial soil of West Bengal.

Conflict of interest

The authors declare that they have no conflict of interest.

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