Foliar Application of Boron can Increase Seed Formation, Seed Yield and Oil Content in Sunflower (cv. BARI Surjamukhi-3)

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Abstract— *A field experiment was conducted at the experimental field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701during winter season of 2022 – 2023. BARI Surjamukhi-3, a popular and promising dwarf variety of sunflower was used in this study as a test crop. The objectives were to know the effect of foliar spray of boron (B) on seed formation, seed yield and oil content in sunflower and to find out the optimum foliar dose of B for maximizing the seed yield. The experiment was conducted in a Randomized Complete Block Design (RCBD) having three replications. The fertilizer boric acid (H_3BO_3) containing 17% Boron (B) was applied at 20-25 and 40-45 days after sowing (DAS) as foliar mode. Five treatments comprised of different foliar doses of B were applied. T_1- control (spray with distilled water), T_2- 50 mg L^{-1} B, T_3- 100 mg L^{-1} B, T_4- 150 mg L^{-1} B and T_5-200 mg L^{-1} B. The foliar application of B significantly increased the seed formation, seed yield and yield contributing characters of sunflower. The treatment T_4 (150 mg L^{-1}B) produced the highest seed yield (2.25 t/ha) that was equal with the treatment T_5 (200 mg L^{-1}B). The minimum unfilled seed (19.00%) was recorded in T_4 (150 mg L^{-1}B), which was identical with the next higher dose T_5 (19.00%) treatment. Foliar application of B also significantly increased the oil content in sunflower seeds. The maximum oil content (39.99%) was recorded in T_5 (200 mg L^{-1}B), which was significantly higher over B control but identical to rest of the treatments. Thus, sunflower grown in B deficient Grey Terrace Soil of Gazipur (AEZ-28) found responsive to foliar application of B with regard to seed formation, seed yield and oil content.*

Keywords— Foliar application, Optimum dose of Boron, Seed sterility, Oil content, Reproductive growth.

I. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is considered as an essential oilseed crop, which grows well in Bangladesh during winter season. The oil of sunflower contains plenty of essential fatty acid such as linoliec and linolenic acid in comparison with rapeseed and mustard oil. But Rabi (winter) season is considered the best for producing sunflower in Bangladesh. The southern regions of Bangladesh is most suitable to grow sunflower after harvesting T. aman rice (BARI, 2023). The area and production of sunflower in 2020-2021 was 0.012 lakh ha and 0.014 lakh MT, respectively (DAE, 2022) and its cultivation and production are gradually increasing. Sunflower, has been recorded to be particularly sensitive to B deficiency and normally used as an indicator for the assessing available B in soils (Oyinlola, 2007). As B is essential for crop growth and can be applied according to crop demand, harmful effects also detected by the applying overdose in early phases of growth (Oyinlola, 2007 and Shorrocks, 1997). Foliar application may be required when the demands are higher than the boron supplied through the soil application. The doses of boron may affect either by positively and negatively the yield and the components in vegetative and reproductive stages of sunflower. The reproductive growth is much sensitive for boron than vegetative growth (Asad *et al.*, 2003). Chatterjee and Nautiyal (2000) reported that the pollen viability and abortion of stamens and pistils, which contribute to poor seed set due to malformed capitulums and consequently low seed yield, due to B deficiency at flowering time. The demand of boron to sunflower varies depending on the stage of plant growth. The critical content of boron at the time of sunflower emergence is 20 mg kg^{-1} of soil (Asad, 2002). That is the reason why some farmers prefer foliar nutrition when applying micronutrients. Many scientists have described the effects of foliar application of boron on the growth and development of sunflower. Boron is an important element, which influenced yields of many crops like sunflower, cotton (Dodas, 2006). However, in depth research regarding the foliar application of B in sunflower for seed formation and its yield is scarce in Bangladesh. Therefore, the present study was carried out with following objectives: (i) to know the effect of foliar spray of boron (B) on seed formation, seed yield and oil content in sunflower and (ii) to find out the optimum foliar dose of B for maximizing the seed yield.

II. MATERIALS AND METHODS

The present investigation was carried out at the research field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during winter season of 2022 - 2023. The study area was under the agro-ecological zone (AEZ)-28 known as Madhupur Tract, which represents Grey Terrace Soil (Aeric Albaquept). The experiment was laid out in a Randomized Complete Block Design (RCBD) having three replications. The unit plot size was maintained 2 m × 2 m. BARI Surjamukhi-3, a dwarf and promising variety of sunflower was used as test crop. Fertilizers were applied at the rate of 140-43-81-29-3 kg ha^{-1} of N-P-K-S-Zn in the form of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate, respectively. In addition, decomposed cowdung @ 5 t ha^{-1} was applied. The entire amount of cowdung and all P, K, S, and Zn were applied at the time of sowing as basal dose, while the rest N was applied in three splits (half at sowing and remaining half N was applied as top dress in two equal splits at 20-25 and 40-45 DAS). The seeds were treated with fungicide, vitavax before sowing.

Seeds were sown on 22 November, 2022 maintaining the spacing of 50 cm from row to row and 25 cm from plant to plant. Irrigation was applied for ensuring desirable soil moisture as per demand of sunflower. Intercultural operations were done as and when necessary.

2.1 Foliar application of boron:

There were five treatments for foliar spray of boron viz. T_1- control (spray with distilled water), T_2- 50 mg L^{-1} B, T_3- 100 mg L^{-1} B, T_4-150 mg L^{-1} B and T_5- 200 mg L^{-1}B. Boron in the form of boric acid (H_3BO_3) containing 17% B were sprayed two times at 20-25 and 40-45 days after sowing (DAS). A hand operated compressed air sprayer was used for foliar application. The spray volume was 10 liter per plot (2.5 Lm^{-2}). The foliar spray was done during morning (around 8:00A.M.).

2.2 Soil sample collection and analysis

Initial soil samples were collected from a depth of 0-15 cm and analyzed well ahead of sowing to know the fertility status of soil (Table 1) for determining the fertilizer requirement of crop. The soil pH measurement was done with a combined glass calomel electrode pH meter as described by Jackson, (1962). Organic carbon was determined by wet oxidation method (Walkley and Black, 1934). The total N was estimated by modified Kjeldahl method. The macro elements like K, Ca and Mg were determined by NH4OAC extractable method and the micro nutrients such as Cu, Fe, Mn and Zn were determined by DTPA extraction method using Atomic Absorption Spectrophotometer (Model SHIMADZU AA-7000). Boron was estimated by $CaCl_2$ extraction method. Phosphorus was measured determined by Bray and Kurtz method while S was estimated by turbidimetric method with $BaCl_2$.

TABLE 1
INITIAL PROPERTIES OF THE SOIL SAMPLES OF EXPERIMENTAL FIELD

Soil Properties	Texture	pH	OM	Ca	Mg	K	Total N	P	S	B	Cu	Fe	Mn	Zn
			(%)	meq 100g^{-1}			%	ppm						
Result	Sandy clay loam	5.3	1.3	6	1.9	0.2	0.07	6	32	0.2	0.9	154	18	3.5
Critical level	-	Acidic	Low	2	0.5	0.1	Low	7	10	0.2	0.2	4	1	0.6

2.3 Initial soil fertility status

The soil of the research field was found acidic in reaction (pH 5.3). The texture was sandy clay loam.

2.4 Plant sample preparation and analysis

The plant samples from each plot were dried maintaining the temperature 65°C in an electric oven around 72 hours then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Digestion of plant samples were done using H_2SO_4 for N and HNO_3-$HClO_4$ (3:1) for other nutrients determination. The grains were ground and N, P, K, Ca, Mg, S, B and Zn contents were determined according to method described by Jones and Case (2018). Atomic absorption spectrophotome was used for metal ion and spectrophotometer (Agiland Technologies, cary 60 UV-Vis) for anion analysis. The accumulatic nutrients in the plant was estimated by multiplying nutrient content by dry plant weight.

2.5 Nutrient uptake

Nutrient uptake was calculated using the formula suggested by Fegeria *et al.* (1997).

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient\%}\times\text{Dry weight (kg h}a^{-1}\text{)}}{100} \tag{1}$$

2.6 Data collection and statistical analysis

The heads of sunflower were harvested during maturity. Five plants were randomly selected from each and every treatment for collecting necessary data such as dry matter, head diameter, number of seed, number of unfilled seed, seed weight, seed yield (t ha^{-1}), B and oil content. All the data were statistically analyzed using STATISTIX-10 and treatment means were separated by multiple comparison test using LSD.

III. RESULTS AND DISCUSSION

Foliar application of B contributed significantly to the yield components, seed yield and oil content in sunflower (**Table 2**). The highest head diameter was observed in T_5 (17.18 cm) that was statistically identical with the T_4 (17.15) and followed by T_3 (15.50) and they were significantly higher over rest of the treatments where the control treatment showed the lowest diameter (12.03 cm). Number of seeds $head^{-1}$ was the highest in T_4 (604.25) treatment which was similar with T_5 (604.14) and the lowest was recorded in T_1 (384.35) and they were statistically dissimilar. The number of unfilled seeds $head^{-1}$ was recorded the highest in boron control (145.97), which was significantly higher over all other treatments. The number of unfilled seeds reduced gradually with increasing dose of B up to 150 mgL^{-1} and remained static for the next higher dose (T_5). The less number of unfilled seeds were recorded in the T_5 (114.80) treatment which was exactly similar with T_4. Al-Amery *et al.* (2011) mentioned similar results in their findings. The hundred seed weight was recorded the maximum in T_4 treatment (7.40g) which was identical with T_5 (7.15g) and both of them were significantly higher over rest of the treatments. The lowest hundred seed weight (4.45 g) was recorded in boron control, which was significantly lower than boron treated plants. The highest seed yield $plant^{-1}$ was produced by the treatment T_5 was (40.01 g $plant^{-1}$) that was similar with T_4 (40.00) followed by T_3 (33.27 g $plant^{-1}$) but the control treatment produced the lowest yield (21.00 g $plant^{-1}$). Mekki (2015), Brighenti and Castro (2008), Sharker and Mohammed (2011) and Al–Amery *et al.* (2011) observed that the higher dose of foliar application of B increased head diameter, number of seeds $head^{-1}$ and seed yield $plant^{-1}$ of sunflower. Bhattacharyya *et al.* (2015) explored the highest sunflower yield and maximum B efficiency with foliar spray of B. Saeed *et al.* (2015) showed that the yield components of sunflower significantly affected with foliar application of boron.

In case of yield (t ha^{-1}) significant differences were observed among the treatments. The highest seed yield (2.25 t ha^{-1}) was recorded with the T_4 treatment where 150 mgL^{-1} of B were applied which was statistically identical with T_5 (2.25) treatment (Table 2). Sunflower yield was significantly higher with boron foliar application in the study of Prabhakar *et al.*, (2021). The unfilled seed percentage was highest in control (37.98) treatment where malformed capitulum were identified but the lowest in T_4 and T_5 treatment (19.00 %), which might have contributed to higher yield in boron sprayed plants. The seed yield might have increased with foliar application of B due to prolonged photosynthetic capacity during flowering period and enhanced seed formation and also for the greater partitioning from increased biomass. Al-Amery *et al.* (2011) expressed that application of B resulted in increased seed yield partly may be due to decreased seed sterility. The reproductive growth required higher amount of B than vegetative stage of growth. So sufficient amount of B might have resulted enhanced growth (Asad *et al.*, 2003). The oil content in seed varied from 36.40 to 39.99%. Similarly, oil yield significantly ranged from 7.71 to 16.92 g/plant. The highest oil content (39.99%) and oil yield (16.92g $plant^{-1}$)) was observed in T_5 treatment, which was statistically identical with T_4 in both the cases. The increase in seed yield and percent oil content in BARI Surjamukhi-3 may be due to collective contribution of yield traits and vigorous seed formation resulted in foliar B application. The significant increase in oil yield might be influenced with the increase in oil content by foliar application of B up to150 mgL^{-1}. Renukadevi and Savithri (2003) mentioned that application of B had brought out a tremendous enhancement in the oil yield of sunflower.

TABLE 2
EFFECT OF FOLIAR APPLICATION OF B ON THE YIELD COMPONENTS, SEED YIELD AND OIL CONTENT IN SUNFLOWER DURING WINTER, 2022 – 2023

Treatment	Head diameter (cm)	No. of seeds head^{-1}	No. of unfilled seeds head^{-1}	Seed yield (g plant^{-1})	Weight of 100 seed (g)	Yield (t ha^{-1})	Unfilled seed (%)	Oil %	Oil Yield (g/plant)
T_1: Control	12.03c	384.35d	145.97a	21.00d	4.45d	2.10d	37.98a	36.4	7.71d
T_2 :50 mgL^{-1}B	14.23b	459.30c	133.19b	27.30c	5.37c	2.15c	29.00b	37.95a	10.60c
T_3:100 mgL^{-1}B	15.50b	532.05b	127.69b	33.22b	6.36b	2.19b	24.00c	38.75a	13.82b
T_4:150 mgL^{-1}B	17.15a	604.25a	114.81c	40.00a	7.40a	2.25a	19.00d	39.98	16.85a
T_5:200 mgL^{-1}B	17.18a	604.14a	114.80c	40.01a	7.15a	2.25a	19.00d	39.99	16.92a
STC	**	**	**	**	**	**	**	NS	**
CV(%)	5.32	5.6	5.88	7.54	5.54	5.49	5.7	4.49	10.74

STC means significance test code, ** indicates significant at 1% level, * indicates significant at 5% level, NS indicates not significant

The stover of sunflower plant after the harvest of seed is regarded as biomass yield. However, the biomass yield also varied significantly due to foliar application of B (Table 3). The highest biomass (3.31 t ha^{-1}) was recorded in T_5 treatment that was statistically and numerically similar with the T_4 (3.30). The control treatment showed the lowest stover (1.79 t ha^{-1}). Al-Amery *et al*. (2011) mentioned that the B application increased dry matter of sunflower. The maximum boron conc. was recorded in T_5 treatment (79.00 ppm) resembling with T_4 (78.42 ppm) and followed by T_3 and T_2. But T_4 and T_3 were statistically dissimilar. The control treatment had the lowest amount (59.00 ppm). Boron uptake (kg ha^{-1}) was significantly varied among the treatments. The highest amount was recorded in T_5 (0.2616 kg ha^{-1}) which was statistically identical with T_4 (0.2587) and that were followed by T_3 (0.2016 kg ha^{-1}) and T_2 (0.1530 kg ha^{-1}). The control treatment was identified with lowest amount (0.1054 kg ha^{-1}). Bhattacharyya *et al*. (2015) revealed the yield maximization followed by the uptake of the plant with foliar application of B.

TABLE 3
BIOMASS YIELD, CONTENT AND UPTAKE OF B IN SUNFLOWER PLANT

Treatment	Biomass yield (t ha^{-1})	B conc. (ppm)	B uptake by plant (kg ha^{-1})
T_1: Control	1.79c	59.00d	0.1054d
T_2 :50 mgL^{-1}B	2.28bc	67.00c	0.1530c
T_3:100 mgL^{-1}B	2.79ab	72.33b	0.2016b
T_4:150 mgL^{-1}B	3.30a	78.42a	0.2587a
T_5:200 mgL^{-1}B	3.31a	79.00a	0.2616a
STC	**	**	**
CV(%)	6.63	4.76	4.78

Conc. means concentration

The seed dry yield, nutrient content and uptake of N, P, K, Zn and B, were presented in Tables 4 and 5. The sufficient amount of variation observed among the treatments for seed yield (kg ha^{-1}). The highest seed yield was recorded in T_4 (1569.33 kg ha^{-1}) treatment. Similar result was observed in T_5 treatment and followed by T_3 (1511.83 kg ha^{-1}) and T_2 (1456.50 kg ha^{-1}) treatment. The T_1 treatment was identified as the lowest one (1396.33 kg ha^{-1}). The application of B increased seed yield according to the findings of Ahmed *et al*. (2011), Jyothi *et al*. (2018) and Al-Amery *et al*. (2011).

The amount of boron concentration (ppm) was identified the highest in T_5 (46.00 ppm) that was similar with T_4 (44.67 ppm) and followed by T_3 and T_2 but the lowest was in T_1 (26.33), the control treatment. Significant differences among the treatments were showed in case of B uptake by seed (kg ha^{-1}). The T_5 treatment exhibited the maximum amount (0.0722 kg ha^{-1}) that was identical with T_4 (0.0701 kg ha^{-1}) and followed by T_3 (0.0585 kg ha^{-1}) and T_2 (0.0466 kg ha^{-1}) treatments. The minimum amount was obtained from the control treatment (0.0367 kg ha^{-1}).

TABLE 4
SEED DRY YIELD, CONTENT AND UPTAKE OF B AND ZN IN SUNFLOWER SEED

Treatment	Seed yield (kg ha^{-1})	B conc. (ppm)	Zn conc. (ppm)	B uptake by Seed (kg ha^{-1})	Zn uptake by Seed (kg ha^{-1})
T_1: Control	1396.33d	26.30d	65.74b	0.0367d	0.092c
T_2 :50 mgL^{-1}B	1456.50c	32.00c	72.99a	0.0466c	0.106b
T_3:100 mgL^{-1}B	1511.83b	38.67b	75.36a	0.0585b	0.114ab
T_4:150 mgL^{-1}B	1569.33a	44.67a	78.12a	0.0701a	0.123a
T_5:200 mgL^{-1}B	1569.33a	46.00a	76.45a	0.0722a	0.120a
STC	**	**	**	**	**
CV(%)	6.14	7.85	4.16	7.79	4.33

TABLE 5
N, P AND K CONTENT AND UPTAKE IN SUNFLOWER SEED

Treatments	N con. (%)	P con. (%)	K con. (%)	N uptake by seed (kg ha-^{1})	P uptake by seed (kg ha-^{1})	K uptake by seed (kg ha-^{1})
T_1: Control	3.42	0.55	1.38b	47.81b	7.63c	19.31b
T_2 :50 mgL^{-1}B	3.48	0.57	1.50b	50.69b	8.25bc	21.89b
T_3:100 mgL^{-1}B	3.61	0.58	1.71a	54.63a	8.82ab	25.86a
T_4:150 mgL^{-1}B	3.62	0.61	1.69a	56.77a	9.52a	26.58a
T_5:200 mgL^{-1}B	3.63	0.6	1.72a	57.02a	9.47a	26.94a
STC	NS	NS	*	**	**	**
CV(%)	2.84	6.12	6.19	3.39	6.35	6.52

Root dry weight, B conc. (ppm), and B uptake by root (kg ha^{-1}) have been described in Table 6. Adequate variation was recorded among the treatments for root dry weight. The highest root dry weight was recorded in T_5 (497.00 kg ha^{-1}) which was identical with T_4 (496.33kg ha^{-1}) and followed by T_3 (414.00 kg ha^{-1}) and T_2 (331.33 kg ha^{-1}). The control treatment showed the minimum value (246.00 kg ha^{-1}). Boron content in the form of ppm was significantly visible. The T_5 (40.66 ppm) identified the maximum concentration that resembled with T_4 (38.84 ppm) and followed by T_3 and T_2. The control treatment expressed the lowest amount (20.33 ppm).

TABLE 6
ROOT DRY WEIGHT, CONTENT AND UPTAKE OF B IN SUNFLOWER ROOT

Treatment	Root dry weight (kg ha^{-1})	B con. (ppm)	B uptake by root (kg ha^{-1})
T_1: Control	246.00d	20.33c	0.0050d
T_2 :50 mgL^{-1}	331.33c	26.00bc	0.0086c
T_3:100 mgL^{-1}	414.00b	32.00b	0.0132b
T_4:150 mgL^{-1}	496.33a	38.84a	0.0192a
T_5:200 mgL^{-1}B	497.00a	40.66a	0.0202a
STC	**	**	**
CV(%)	5.32	11.01	10.58

The boron uptake by root (kg ha^{-1}) revealed remarkable variation among the treatments. The highest amount was recorded in T_5 (0.0202 kg ha^{-1}) which was identical with T_4 (0.0192 kg ha^{-1}) and followed by T_3 (0.0132 kg ha^{-1}) and T_2 (0.0086 kg ha^{-1}) treatment. T_1 (0.0050 kg ha^{-1}) treatment identified with the lowest amount. Asad *et al*. (2003) expressed enhancement growth with boron foliar application but the little dependence of the concentration in root environment in sunflower.

The Zn concentration of fruit increased by the application of B to a certain level finally decreased its concentration with higher rate of B application. Percent Zn varied from 65.74 to76.45 ppm that also resulted in the maximum Zn uptake for the T_4 treatment (0.123 kg ha^{-1}). The lowest Zn uptake was recorded as 0.092 kg ha^{-1}.

The effect of B on the concentration of Nitrogen (N), Phosphorus (P), and Potassium (K) expressed that added B increased the concentration of P in sunflower seed, but the increment was not sufficient (Table 2). The concentration as well as uptake of nutrients such as N, P, K were influenced in bitter gourd upto certain level in the studies of Banu *et al*. (2024). The minimum N (3.42%) and P concentrations (0.55%) were found in control treatment while the maximum N concentration (3.63%) was found in T_5 and the maximum P (0.61%) was found in T_4 treatment. The N uptake by seed reached to the peak in T_5 (57.02 kg ha^{-1}) treatment which was identical with T_4 (56.77 kg ha^{-1}). The P conc. (%) was found to lie in between 0.55% and 0.61% that also reflected in P uptake by seed kg ha^{-1} limiting between 7.63 kg ha^{-1} and 9.52 kg ha^{-1}. The K conc. (%) was the highest in T_5 (1.72%) treatment. The K uptake by seed was the top in T_5 treatment (26.94 kg ha^{-1}) which however was identical with T_4 (26.58 kg ha^{-1}) and T_3 treatments. The present study revealed N P, K, Zn and B content showed synergistic relationship with B application in soil up to a certain level.

IV. CONCLUSION

Foliar application of B two times at 20-25 and 40-45 days after sowing of seeds, i.e. in vegetative and pre-flowering stage, respectively significantly contributed to increase seed formation, seed yield, biomass yield, oil content in sunflower (BARI Surjamukhi-3). Boron application in the form of foliar mode also decreased seed sterility and increased the B concentration and uptake by the plants. Boron @ 150 mg L^{-1} as foliar application containing the volume of 10 liters per plot (2.5 Lm^{-2}) appeared as the best dose for the cultivation of sunflower in Grey Terrace Soil under AEZ 28 and similar soils in Bangladesh.

NOVELTY STATEMENT

The present findings indicated that up to a certain level of B application to soil, N P, K, Zn and B content showed synergistic effect. This type of research was conducted first time in Bangladesh

AUTHOR'S CONTRIBUTION

Most. Bilkis Banu: Conceptualization and methodology of the study. Supervision, soil chemical analysis collection of data and analysis using Statistics10. Writing results and discussions, reference collection ect.

Habib Mohammad Naser: Conceptualization and supervision, providing logistic supports.

Mohammad Quamrul Islam Matin: Editing, proofreading, plagiarism, review collection.

Mohammed Harun or Rashid: Supervision, data collection, editing.

Rabiul Islam: Supervision, data collection, editing.

Mohammad Motasim Billah: Data collection, editing.

Md. Mahmudur Rahman: Review collection, editing.

Atikur Rahaman: Data collection and review collection.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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REFERENCES

[1] Ahmed, N., Abid, M., Ahmad, F., Aman Ullah, M., Javid, Q and Ali, M.A., 2011. Impact of boron fertilization on dry matter production and mineral constitution of irrigated cotton. Pak. J. of Bot. 43(6): 1903-2910.

[2] Asad, A., Blamey, F.P.C. and Edwards, D.G., 2003. Effects of boron foliar applications on vegetative and reproductive growth of sunflower. Annals of Bot., 92:565-70. Doi:10.0193/aob/mcg179

[3] Asad, A., 2002. Boron requirements for sunflower and beet. J Plant Nutri., 25:885-899.

[4] Al-Amery, M., Hamza, J. H., and Fuller, M. P., 2011. Effect of Boron Foliar Application on Reproductive Growth of Sunflower (*Helianthus annuus* L.). Intl. J. of Agron. doi:10.1155/2011/230712.

[5] Brighenti, A. M. and Castro, C., 2008. Boron Foliar Application on Sunflower (*Helianthus annuus* L.) Associated with Herbicides. Helia., 31 (48): 127-36.

[6] Banu, M.B., Akter, M., Sultana, S., Khatun, M.R. and Naser, H.M. 2024. Effects of Boron Application on Yield and Quality of Bitter Gourd. Bangladesh J. Soil. Sci., 40(1): 113-121.

[7] Bhattacharyya, K., Mondal, J., Banerjee, H., Alipatra, A., Ray Krishnendu and Phonglosa, A., 2015. Boron Fertilization in Sunflower (*Helianthus annuus* L.) in Inceptisol of west Bengal, India, Communications in Soil Science and Plant Analysis. https://www.tandfonline.com/loi/lcss20

[8] BBS (Bangladesh Bureau of Statistics). 2023. Bangladesh Bureau of Statistics, Dhaka, Bangladesh

[9] BARI (Bangladesh Agricultural Research Institute). 2023. Annual Research Report 2022-23, Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur-170. pp. 138.

[10] Chatterjee, C. and Nautiyal, N., 2000. Development aberrations in seeds of boron deficient sunflower and recovery. J. of plant nutrition., 23: 835-841.

[11] DAE (Department of Agricultural Extension). 2022. Khamarbari, Farmgate, Dhaka-1215.

[12] Dordas, C., 2006. Foliar boron application affects lint and seed yield and improves seed quality of cotton grown on calcarious soils. Nutr. cycl. Agroecosystems., 76:19 28.

[13] Fegeria, N.K., Baliger, V.C. and Jones, C.A., 1997. Growth and mineral nutrition of field Crops, New York, USA.

[14] Jyothi, P., Anjaiah, T., Murthy, I.Y.L.N., Naik Rajeshwar and Hussain, S.A., 2018. Seed yield and nutrient uptake of sunflower (*Helianthus annuus* L.) as influenced by different levels of boron and potassium in sandy loam soil. Int. J. Curr. Microbial. App. Sci., 7(7):3684-3692.

[15] Jackson, M.L., 1962. Soil Chemical Analysis. Prentice Hall Inc. Englewood Cliffs, N.J.

[16] Jones, J.B and Case, V. W., 2018. Sampling, Handling, and Analyzing Plant Tissue Samples. Jo & Sons, Ltd, pp. 389-427.

[17] Mekki, B. ED., 2015. Effect of Boron Foliar Application on Yield and Quality of Some Sunflower (*Helianthus annuus* L.) Cultivars. J. of Agril. Sci. and Tech., B 5:309-316. doi: 10.17265/2161-6264/2015.05.002.

[18] Oyinlola, E. Y., 2007. Effect of Boron Fertilizer on Yield and Oil Content of Three Sunflower Cultivars in the Nigerian Savanna. J. of Agron. 6 (3): 421-6.

[19] Prabhakar, K., Kalyani, D. L., Nayak, S. B., Venkataramanamma, K., Neelima, S. and Kumar D. S., 2021. Effect of boron foliar application at Critical growth stages on sunflower (*Helianthus annuus* L.) seed yield and oil yield. The Phar. Inno. J., 10(8): 910-913.

[20] Renukadevi, A. and Savithri, P., 2003. Sunflower (*Helianthus annuus*) Oil Yield and Quality as Influenced by Boron Application. Madras Agric. J., 91: 74-6.

[21] Shorrocks, V. M., 1997. The occurrence and correction of boron deficiency. Plant and Soil, 193(1-2): 121–148.

[22] Statistix for Windows. 1998. Analytical Software. Tallahassee, Fla, USA.

[23] Shaker, A. T. and Mohammed, S. A., 2011. Effect of Different Levels and Timing of Boron Foliar Application on Growth, Yield and Quality of Sunflower Genotypes (*Helianthus annuus* L.). Mesopotamia J. of Agric., 39 (3): 16-25.

[24] Saeed, U., Alam, S., Hussain, S., Khan, A., Ameen, A., Li, J. and Shakoor, A., 2015. Impact of foliar application of boron on growth and yield of sunflower (*Helianthus annuus* L.) under different irrigation conditions. Aca. J. of Agril. Res., 3(9): 219-225. DOI: 10.15413/ajar.2015.0129

[25] Walkey, A.J. and Black, I. A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science. 37:29-38. doi: 10.1097/00010694-193401000-00003.