ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 71 17 Number 5, 2023

EVALUATION OF MANAGEMENT APPROACHES SUITABLE FOR IMPROVING THE PRODUCTIVITY OF *HELIANTHUS ANNUUS* L. IN THE SALT-AFFECTED REGION

Md. Atikur Rahman[1], Sharif Ahmed[2], Ferdousi Begum[3], Pryanka Roy[3], Ahmed Gaber[4], Akbar Hossain[5]

[1] Spices Research Center, Bangladesh Agricultural Research Institute (BARI), Bogura-5800, Bangladesh
[2] International Rice Research Institute, Bangladesh Office, Dhaka 1213, Bangladesh
[3] Oil Seed Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur-1701, Bangladesh
[4] Department of Biology, College of Science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia
[5] Division of Soil Science, Bangladesh Wheat and Maize Research Institute, Dinajpur 5200, Bangladesh

Link to this article: https://doi.org/10.11118/actaun.2023.017
Received: 8. 2. 2023, Accepted: 5. 9. 2023

Abstract

In an unfavourable environment, best management practices can greatly reduce the yield gap of many crops; however, the performance of best management practices on sunflower yield and economics in salt-affected low-intensive cropping areas of Bangladesh has yet to be determined. Sunflower (*Helianthus annuus* L.) cultivation in the coastal areas of Bangladesh faces significant challenges, such as increasing soil salinity in the sowing period, lack of sweet water for irrigation, an insufficient supply of quality seeds of high-yielding varieties, and inadequate farmers' knowledge of best production practices. Therefore, the study aimed to evaluate management approaches and varieties to enhance the productivity of sunflowers in salt-affected regions. The study was conducted in two consecutive *Rabi* seasons (2014–2015 and 2015–2016) in Benarpota, Satkhira, Bangladesh. The trial included two popular sunflower varieties (BARI sunflower 2, and SVS 00901) and three management practices (poor, moderate, and best management). Poor and moderate management practices were identified based on the farmers' survey in this area. The best management practices ware decided based on the BARI recommended practices. In both years, the seed yield of BARI sunflower 2 had 10–15% higher than the seed yield of the variety SVS 00901. The best management practices had 25–30% and 35–42% higher seed yields of sunflower than the moderate and poor management, respectively. The best management practices had always higher gross returns, and across varieties, it was 25–30% and 35–40% higher than the moderate and poor management practices resulting in 30–32% and 30–36% higher net return, respectively. Best management practices greatly reduced the salinity level of soil during the cropping period, hence, the salinity stress was comparatively lower than the poor and moderate management. Best management practices with quality sunflower varieties can boost the productivity and profitability of sunflower in coastal Bangladesh and can increase households' income by increasing the cropping intensity.

Keywords: sunflower, management approaches, cultivars, coastal regions, crop intensification

Significance Statement

Soil salinity is a rising threat all over the world due to its toxic effect to reduce water uptake in crops and soil fertility. Best management practices with salt-tolerant variety can greatly reduce the yield gap as well as farmers' profit in the saline-affected land. The crop sunflower is found a potential option in coastal Bangladesh during the rabi season when a significant amount of land remains fellow due to soil salinity level increment. Sunflower can tolerate moderate salinity levels and is a profitable crop for the coastal region if it manages well. Among these tested sunflower cultivars, BARI sunflower 2 is a potential variety suitable for the coastal ecosystem of Bangladesh.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the world's fourth-largest oil-seed crop and is an important minor crop in Bangladesh. It is a member of the Compositae family and native to North America and has been cultivated in Bangladesh on a small basis since 1975 (Khatun *et al.*, 2016). It features a large showy flower and a great number of seeds, each of which contains 40–47% edible oil (Zheljazkov *et al.*, 2008). In comparison to rapeseed-mustard oil, sunflower oil is high in critical fatty acids like linoleic and linolenic acid and does not contain dangerous Erucic acid, making it favourable to heart patients (Konuskan *et al.*, 2019). In Bangladesh, an acute shortage of edible oil has been prevailing for the last several decades (Khatun *et al.*, 2016). According to Bokhtiar *et al.* (2023), Bangladesh produces 0.4 million tons of edible oil while the demand is 1.9 million tons. Sunflower oil could help minimize the gap in edible oil production and consumption in Bangladesh.

Sunflowers can be cultivated effectively in a wide range of climates and are regarded as a crop that can adapt to a variety of environments. It has a short growing season, is drought tolerant, and can thrive in a variety of soil types (from sands to clay), and pH levels (5.7–8) (Khan *et al.*, 2012). Its deep and branched tap root system, which penetrates to the deeper zone and assists the plant under water stress, makes it an extremely effective user of soil moisture. Even in the sub-soil and on heavy clay soils it utilizes moisture reserves far more effectively. According to a classification based on the water stress day index, Sunflower is classified as a moderately sensitive crop to salinity, with a tolerance level of 2–12 ds/m (Katarji *et al.*, 2003).

Sunflower is a photo-insensitive crop that can grow in Bangladesh in both *Rabi* and *Kharif* seasons in all parts of Bangladesh (Khatun *et al.*, 2016). But *rabi* (winter) season is the best for the growing of sunflowers. Due to its potential to salinity and drought stress tolerance, it is a profitable crop in the context of climate change.

Salinity has severely restricted global agriculture in arid and semiarid regions. As the intensity of land usage increases around the world, this stress is becoming ever more prevalent. In Bangladesh, about 0.83 million hectares (MH) out of 2.85 MH of coastal and offshore territories are arable lands (Hoque and Haque, 2016). This arable land accounts for more than a third of all cultivable land in the country. In the coastal districts, agricultural land usage is particularly low and the majority of this area is impacted by varying salinity gradients (Parvin *et al.*, 2017). Low crop intensity in saline areas is mostly owing to unfavourable soil salinity and lack of good irrigation water during the dry season (Rahman and Ahsan, 2011). Increasing cropping intensification in the southern saline region of Bangladesh is a national priority. *Aman* rice is the main crop in the medium salt and irrigation water-short area of coastal Bangladesh (Rashid *et al.*, 2014). To intensify the crop in these areas necessitates a suitable succeeding crop with early planting in moist soil to avoid damage from storm surges and water-logging caused by rainfall in May (Murad *et al.,* 2018).

Flood and tidal water recede in the coastal area from October to late December. Depending on the topographical position and drainage infrastructure, water recedes from a 24% area in October to a 53% area in November and mid-December, and a 23% region in late December (Haque, 2006). The majority of the coastal areas are dominated by medium highlands, with flooding depths ranging from 0.3 to 0.9 meters. At least two crops can be grown on this type of land. Because of its vast adaptation and acclimation, strong photosynthetic potential, and high harvest index, sunflower production may be suitable in this environment (Agele *et al.,* 2007). Soil salinity usually starts to increase from mid-March, when sunflower vegetative growth is at its peak (Hossain *et al.*, 2018). Recently, sunflower production in the coastal areas is increasing; however, farmers are not getting enough profit due to its lower yield (Rashid *et al.,* 2014). The main reasons for the lower yield are to lack of quality variety and appropriate management practices such as optimum sowing, fertilizer management, and irrigation management, weed management, etc. Farmers mostly grow the variety locally available, and after sowing them usually don't do any further management or very poor management. Farmers usually don't use any management inputs after sowing, because they don't like to invest in the management practices of sunflowers. But it is found that sunflower is very profitable in the coastal areas if farmers get higher yields using quality variety and provide inputs in a timely (Rashid *et al.,* 2014). The best agronomic management can greatly help to increase productivity by manipulating the environment and as well as helps plants to provide their requirement when needed. Although best management practices can increase yield and profitability, however, for sunflower production in the saline soil of Bangladesh has not been studied well. We hypothesized, the combination of quality variety and good agronomic management boosts the sunflower yield, and as well as farmers' profit. To keep this in mind, this experiment is undertaken to evaluate the varieties and different levels of agronomic management on sunflower yield and profitability in saline-affected areas in Bangladesh.

MATERIALS AND METHODS

Experimental Site Details

The field experiments were conducted at the Agricultural Research Station (ARS), Bangladesh Agricultural Research Institute (BARI), Benarpota, Satkhira (22°43' N and 89°6' E) during the rabi season of 2014/15 and 2015/16 to find out the suitable variety and better bet management practices for the sustainable sunflower production in salt-affected low intensive cropping area of Bangladesh. The trial area is under agro-ecological zone number 13 the Ganges Tidal Floodplain, an area is underlain by recent and sub-recent alluvium which has been deposited under either tidal or meandering conditions within the last 1000 years (UNDP and FAO, 1988). Soil textural classes range from silty clay loam to clay. About 82% of the area is subjected to shallow flooding during monsoon and tidally deposited sediments are predominantly clay in nature with the shallow ground water table. The soils are saline in nature and it varies from low salinity to very high salinity. The climate of the area is Subtropical in nature, with an average annual rainfall of 1690 mm and peak rainfall time from July to August. January is the coolest month and the monthly mean minimum temperature is 12.1 °C, and April and May are the warmest months, and the mean monthly maximum temperature is 35.6 °C. The soil of the trial fields at 0–15 cm depth was clay in texture, having 41.0% sand, 17% silt, and 42% clay and pH value of 6.6 with a bulk density of 1.67–1.86 Mg m^{-3}. The detailed physical and chemical properties of the study field are shown in Tab. I. The cropping intensity is very less in this area and the major cropping pattern follows rice-fellow-fellow means rainy season rice (*Aman*) and then no crop in the *rabi* and *Kharif-1* seasons.

Treatments and Design

The study included two sunflower varieties (BARI sunflower 2 and SVS 00901) and three management practices (poor, moderate, and best management). Varietal characteristics and detailed management practices are shown in Tab. II. The experimental design followed RCB two factors with three replications. The treatment plot size was 3 m × 4 m and the buffer distance of each plot was 0.50 cm.

Crop Management

Seeds of each variety were sown on 1 December 2014–2015 and 19 November 2015–2016 with a distance of 50 cm row and plant to plant 25 cm. The land was prepared with four passes using a four-wheeled tractor. Two seeds were sown in a depth of 2–3 cm hole and comparatively, a weak seedling was thinned after 15 days of emergence to maintain a uniform plant population. The full amount of triple superphosphate, muriate of potash, gypsum, zinc oxide, boric acid, and half of the urea were broadcasted in the experimental plot at the time of final land preparation as per treatment. The rest half of the urea was applied as top dressing at 45 days after sowing just before flowering. Intercultural operations such as weed management and irrigation were done as per the treatments.

Data Collection

The initial plant population was counted 20 days after sowing and the final plant population just before harvesting. Plant height was measured during the harvesting time from the randomly selected 10 plants. Days to maturity were counted sowing to florets in the centre of the flower disk were shriveled and heads were downturned. The diameter of inflorescence, no. of seeds/ inflorescence, and 1000 grain weight were measured by randomly

I: *Soil physical and chemical properties of the study field, Benarpota, Bangladesh*

Sand	Silt	Clay	Textural class	pH	Organic matter	Total N	Ca	Mg	K	P	S	B	Cu	Fe	Mn	Zn
%							meq/100 ml			µg/ml						
41	17	42	Clay	6.6	1.55	0.11	28.7	16.1	0.57	22.9	53	0.65	1.4	38	10.9	1.4

II: *Varietal characteristics and detailed management practices followed in the study*

Variety	Characteristics
BARI sunflower 2	Plant height 125–140 cm, life cycle 95–100 days, seed yield 1.8–2.1 t/ha, and 1000 seed weight 65–70 gm.
SVS 00901	Plant height 90–130 cm, life cycle 95–102 days, seed yield 2–2.3 t/ha, and 1000 seed weight 60–70 gm.
Management practices	Details
Poor	No thinning after emergence. No irrigation and weeding. Not applied any fertilizer.
Moderate	One weeding cum thinning at 30 DAE and One Irrigation at 30 DAE. Applied fertilizer at the rate of 43-12-20-15 kg ha^{-1} of N-P-K-S, respectively.
Best	Weeding cum thinning at 30 DAE and 2nd weeding at 60 DAE. Two times irrigation at 30 and 60 DAE. Applied fertilizer at the rate of 86-24-40-30-3-1-0.8 kg ha^{-1} of N-P-K-S-Mg-Zn-B, respectively.

selecting 10 inflorescences from each plot. Seed yield and stover yield were measured after harvesting of a plot of 3 m × 4 m. Soil salinity (dS/m) was measured by a EC meter (HANNA: HI 9835) at sowing, emergence, vegetative growth period, pre-flowering, heading, maturity, and at harvesting.

Weather Data

Daily temperatures and rainfall data during the trial period were collected from the nearby weather station and shown in Fig. 1.

Economic Analysis

Human labour used for different management operations such as land preparation, weeding, irrigation, and harvesting were recorded for each treatment during each operation. The time required to complete each operation was recorded treatment-wise and expressed as person-days ha^{-1} considering 8 h to be equivalent to one person-day. The labour costs were calculated using the current labour wage reported by farmers. Gross income was calculated by multiplying sunflower seed yields with the market price of seed in the local market.

Statistical Analysis

Prior to doing an analysis of variance (ANOVA), the measured data were subjected to homogeneity and normality tests. The results showed that the data were normally distributed to perform subsequent ANOVA. As a result, JMP13 (SAS Institute Inc., 2017) was used to do the combined ANOVA for the data from the two seasons. The Tukey's Honestly Significant Difference (HSD) test and t-test were used to separate the means for management practices and varieties, respectively at the $p \leq 0.05$ level.

RESULTS

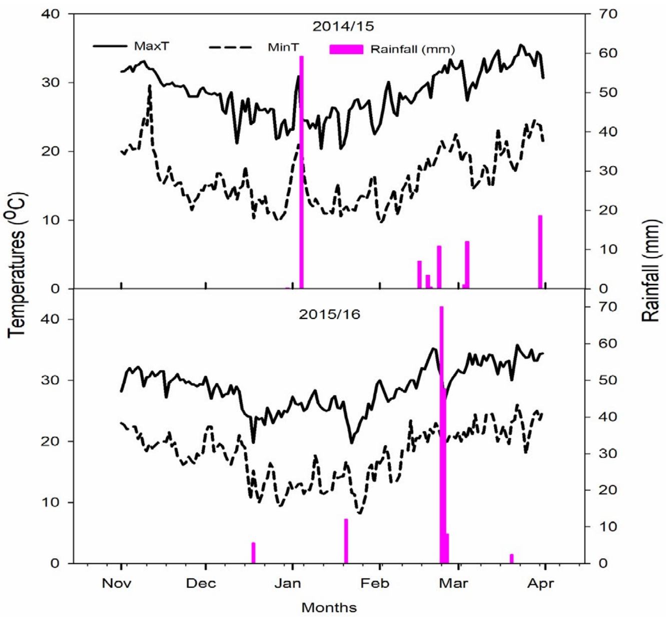
Variety and Management Practices on Sunflower Growth, Development, and Yield Performance

The initial and final plant population were not affected by the varieties, management practice and their interaction. The plant height was affected by the varieties and management practices but not their interaction (Tab. III).

Across management practices, the BARI sunflower 2 had a higher plant height than the SVS 00901, and best and moderate management practices had higher plant height than the poor management (Tab. IV). Inflorescence diameter was not affected by the varieties but differed due to management practices and the highest value was recorded from the best management practice followed by moderate and poor management practices (Tab. IV).

The growth duration was affected by the varieties and management practices; however not their interaction (Tab. III). BARI sunflower 2 had 3–4 days higher growth duration than the variety SVS 00901 (Tab. IV). Considering the management practices, the best management required more time to complete the life cycle, and compared with the poor management practice it was 4–5 days delayed to mature (Tab. IV). The number of seeds inflorescence^{-1} was affected by the varieties as well management practices but not their interaction (Tab. III). Across management practices, the BARI sunflower 2 had 8–10% higher seeds inflorescence^{-1} than the variety SVS 00901 (Tab. V).

Across variety, the best management practice had 8–10% and 17–23% higher seeds inflorescence^{-1}



1: *Daily temperatures and rainfall during the study period in 2014/15 and 2015/16 at Benarpota, Satkhira*

III: *Analysis of variance results (p ≤ 0.01) of different parameters measured in the study*

Source of variance	Initial plant population	Final plant population	Plant height	Inflorescence diameter	Growth duration	1000-grain weight	Stover yield
Year (Y)	NS	NS	<.0001	<.0001	<.0001	0.0003	NS
Variety	NS	NS	<.0001	NS	0.027	NS	NS
Management	NS	NS	<.0001	<.0001	0.01	0.0005	0.0004
Variety × Management	NS	NS	NS	NS	NS	NS	NS
Source of variance	**Seed yield**	**Seeds/ inflorescence**	**Gross return**	**Total variable cost**	**Net profit**	**BCR**	**Soil salinity**
Year	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Variety	<.0001	<.0001	0.006	NS	<.0001	<.0001	NS
Management	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Variety × Management	NS	NS	NS	NS	NS	NS	NS

NS: non-significant; values less than 0.05 is not significant

IV: *Initial and final plant population (numbers/12 m^{-2} areas), plant height (cm), the diameter of inflorescence (cm) and days to maturity of sunflower as affected by variety and management practices*

Treatments		Initial plant population		Final plant population		Plant height (cm)		Inflorescence diameter (cm)		Growth duration	
		Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
Variety	BARI*	96	89	82	86	113 a	134 a	12	16.4	104 a	101 a
	SVS#	88	93	77	90	90 b	128 b	11.5	16.8	100 b	98 b
Management	Poor	92	90	79.5	87.5	88 b	115 b	8.5 c	13.2 c	100 b	97 b
	Moderate	91	90	79.0	88	104 a	133 a	12.8 b	17.3 b	101 b	99 b
	Best	92	91	79.5	89	113 a	144 a	13.7 a	19.2 a	104 a	102 a

*BARI sunflower 2; #SVS 00901, Y1: Year 1, Y2: Year 2, different lowercase letters in the column indicates significance. Without letter means they are not significant.

V: *Number of seeds/inflorescence, 1000 grain weight (gm), seed yield (t/ha), and stover yield (t/ha) of sunflower as affected by variety and management practice*

Treatments		Seeds/ inflorescence		1000 grain weight (gm)		Seed yield (t/ha)		Stover yield (t/ha)	
		Y1	Y2	Y1	Y2	Y1	Y1	Y1	Y2
Variety	BARI*	401 a	420 a	59.9 a	57.0	1.66 a	1.85 a	2.92	3.25
	SVS#	367 b	386 b	58.2 b	56. 7	1.49 b	1.63 b	2.85	3.11
Management	Poor	316 c	369 c	58.1 b	54.5 c	1.16 c	1.48 c	2.71 c	2.73 b
	Moderate	375 b	397 b	59.5 a	56.6 b	1.47 b	1.65 b	2.88 b	2.97 b
	Best	408a	443 a	59.6 a	59.6 a	1.99 a	2.31 a	3.08 a	3.84 a

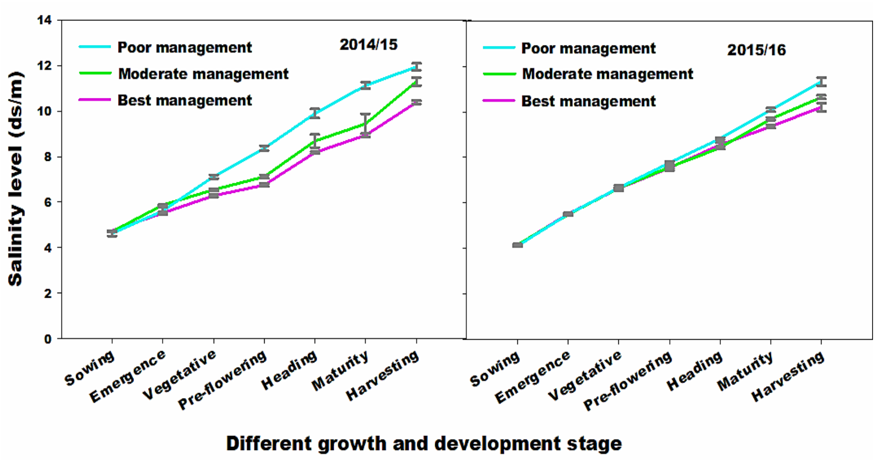
*BARI sunflower 2; #SVS 00901, Y1: Year 1, Y2: Year 2, different lowercase letters in the column indicates significance. Without letter means they are not significant.

than the moderate and poor management practices, respectively (Tab. V). The 1000 grain weight was affected by the varieties in the first year but not in the second year and affected by the management practices in both years (Tab. III). In the first year, BARI sunflower 2 had a higher 1000-grain weight than the variety SVS 00901. The best management practice had 1.5 to 5 gm higher 1000 grain weight than the poor management (Tab. IV). The sunflower seed yield was strongly affected by the varieties and management practices and in both years the highest seed yield (1.66 to 1.85 t ha^{-1}) was recorded from the variety BARI sunflower 2, and the second year yield was higher than the first year. Considering the management practice, the best management had 25–30% and 35–42% higher seed yield than

VI: *Gross return, total variable cost, net return, and benefit-cost ratio (BCR) as influenced by variety and management practice*

Treatments		Gross return (US$/ha)		Total variable cost (US$/ha)		Net return (US$/ha)		BCR	
		Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
Variety	BARI*	1900 b	2114 a	911	917	989 a	1197 a	2.10	2.31
	SVS#	1810 a	2058 b	905	923	905 b	1135 b	2.00	2.23
Management	Poor	1396 c	1763 c	628 c	666 c	768 c	1097 b	2.22 a	2.65 a
	Moderate	1765 b	1966 b	919 b	903 b	846 b	1063 b	1.92 b	2.19 b
	Best	2388 a	2753 a	1176 a	1192 a	1212 a	1561 a	2.03 b	2.32 b

*BARI sunflower 2; #SVS 00901, Y1: Year 1, Y2: Year 2, different lowercase letters in the column indicates significance. Without letter means they are not significant.



2: *The salinity level of the study field as influenced by the management practices*

the moderate management and poor management, respectively. Stover yield was not affected by the varieties but affected by the management practices and compared to best management practices, the poor and moderate management had 6–20% and 12–28% lower stover yield, respectively.

Variety and Management Practices on Sunflower Economics

The gross return was affected by the variety as well as management practices but not their interaction and the BARI sunflower 2 had a 2–5% higher net return than the SVS 00901 (Tab. VI). The best management practice had always higher gross returns, and across varieties, it was 25–30% and 35–40% higher than the moderate and poor management practices, respectively. The total variable cost was not affected by the varieties but affected greatly by the management practices (Tab. III). The highest variable cost (1176–1192 US$/ha) was involved with the best management practice which was 21–24% and 44–46% higher than the moderate and poor management practices, respectively (Tab. VI).

The net return was affected by the varieties as well as management practices and the BARI sunflower 2 had a 5–8% higher net return than the variety SVS 00901. The best management practice had 30–32% and 30–36% higher net return than the moderate and poor management, respectively. The benefit-cost ratio (BCR) was not affected by the varieties, however, affected by the management practice and significantly similar BCR was found from the moderate and poor management and which were significantly lower than the best management (Tab. VI).

Variety and Management Practices on Soil Salinity

Soil salinity increased with the increase of sunflower growth and among management practices, the salinity level difference was more pronounced at the later growth stage e.g., in 2014–2015 season up to emergence and 2015–2016 season up to heading salinity level were not differ (Fig. 2).

Salinity levels during the cropping period ranged from 4 to 12 ds/m. With the increase of crop growth stage, the lower salinity value was recorded from the best management practice, followed by moderate management and poor management. Among management practices, the salinity level difference was higher in the first year than in the second year (Fig. 2).

DISCUSSION

The yield and growth parameters in the current study were greatly affected by management practices. Plants in poor and moderate management received a lower resource for their growth and development and in addition, best management practices also reduced the soil salinity level. The results of our study are supported by the previous study of Isayenkov and Maathuis (2019) who reported the high concentration of salts in soils reduces water uptake, induces water stress, and inhibits the growth and development of plants. Rehman and Hussain (1998) reported sunflower plant height declined as salinity increased, with reductions of 22% at EC 10 dS m^{-1}. In the present study, compared to best management, poor management found 20–25% lower plant height and it was mainly due to best management practice received two times irrigations, well weed control and recommended dose of fertilizer which provided a congenial environment to crop to grow and in addition slightly declined the soil salinity level (Fig. 2).

Salinity data in the current study shows that soil salinity levels increased gradually with the time of crop growth and development. Similar results on maize in the coastal region of Bangladesh were reported by Murad *et al.* (2018), that the soil salinity levels increased gradually over the maize growing period and peaked at the harvesting time. The maize and sunflower both are cultivated in the *rabi* season in coastal Bangladesh.

The soil salinity during the germination of sunflower in the current study ranged from 4–4.5 ds/m. The initial plant density was not affected by the salinity level means sunflower can tolerate some extent of salinity during germination. Seed germination is the first and most critical stage in the plant's life cycle on which the seedling establishment and growth initiation rely. Hafeez *et al.* (2017) found more than 60% germination of all sunflower varieties when imposed to 8.33 ds/m salinity level. The final plant population was slightly lower (5–12%) than the initial plant population, mainly due to some plants damaged due to insects and disease infestation. Murad *et al.* (2018) reported soil salinity of maize fields is reduced when freshwater apply as irrigation. Tolga *et al.* (2001) reported for the maximization of sunflower yield, and maintenance of proper moisture through the supply of irrigation water particularly applied at various critical growth stages of the crop noticeably influenced the seed yield. The best management practice had a 35–42% higher seed yield in the current study was mainly due to two times weed management, two times irrigations, and recommended fertilizer management greatly helped to obtain a higher yield. Wanjari *et al.* (2000) reported uncontrolled weed growth reduced the seed yield of sunflower by up to 55%.

CONCLUSION

In conclusion, the evaluation of management approaches and varieties aimed at improving the productivity of sunflower in the salt-affected regions of Bangladesh has yielded valuable insights. The study has provided a comprehensive understanding of the impact of management practices on sunflower productivity in salt-affected areas. Best management practices with salt-tolerant variety can greatly reduce the yield gap as well as farmers' profit in the saline-affected land. BARI sunflower 2 is a potential variety of sunflower for coastal Bangladesh and large-scale expansion of this variety is urgent to make sunflower more profitable. Overall, the findings of this study hold great potential to revolutionize sunflower cultivation practices in salt-affected regions, leading to increased productivity, improved livelihoods for farmers, and a more resilient agricultural sector in Bangladesh.

Funding: The study was financially supported by Oil Seed Research Center (ORC), Bangladesh Agricultural Research Institute (BARI), Satkhira, Bangladesh. The study was also funded by the Deanship of Scientific Research, Taif University, Taif, Saudi Arabia.

Institutional Review Board Statement

Not applicable.

Data Availability Statement

Not applicable

Conflict of Interests

The authors declare no conflict of interest.

Acknowledgements

The authors warmly applaud the Oil Seed Research Center (ORC), BARI, Gazipur, Bangladesh and Agricultural Research Station (ARS), BARI, Satkhira, Bangladesh for their great technical and financial support. The researchers would like to acknowledge the Deanship of Scientific Research, Taif University for funding this work.

REFERENCES

AGELE, S. O., MARAIYESA, I. O. and ADENIJI I. A. 2007. Effects of variety seed set efficiency in late season sunflower (*Helianthus Annus* L.) in a humid zone of Nigeria. *Academic Journals*, 2: 80–88.

ANGADI, S. V. and ENTZ, M. H. 2002. Agronomic performance of different stature sunflower cultivars under different levels of interplant competition. *Can. J. Plant Sci.*, 82(1): 43–52.

ASHRAF, M. Y., AWAN, A. R. and MAHMOOD, K. 2012. Rehabilitation of saline ecosystems through cultivation of salt tolerant plants. *Pak. J. Bot.*, 44: 69–75.

BADHAN, A. and MOUSUMI, M. A. 2020. Farmers' Problems Associated with Cultivation of Sunflower: A Case Study of Barguna District, Bangladesh. *Asian Journal of Agricultural Extension, Economics & Sociology*, 38(11): 8–14.

BOKHTIAR, S. M., ISLAM, S. M. F., MOLLA, M. M. U., SALAM, M. A. and RASHID, M. A. 2023. Demand for and Supply of Pulses and Oil Crops in Bangladesh: A Strategic Projection for These Food Item Outlooks by 2030 and 2050. *Sustainability*, 15(10): 8240. https://doi.org/10.3390/ su15108240

DE LA VEGA, A. J. and HALL, A. J. 2002. Effects of Planting Date, Genotype, and Their Interactions on Sunflower Yield: I. Determinants of Oil-Corrected Grain Yield. *Crop Science*, 42(4): 1191–1201.

HAFEEZ, A., ARSHADULLAH, M., RASHEED, M., MAHMOOD, I. A., HYDER, S. I., AAMIR, S. S., SHAABAN, M. and MAHMOOD, T. 2017. Effect of soil salinity on germination and growth of sunflower (*Helianthus annuus* L). *J Innov Bio-Res*., 1(1): 46–51.

HAQUE, S. A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. *Pakistan J. Botany*, 38(5): 1359–1365.

HOQUE, M. Z. and HAQUE, M. E. 2016. Impact of climate change on crop production and adaptation practices in coastal saline areas of Bangladesh. *Intl. J. Adv. Res.*, 2(1): 10–19.

HOSSAIN, M. K., ISLAM, M. M., MAMUN, A. A. and MAMUN, S. M. A. 2018. Performance of sunflower genotypes in non-saline and saline soils of southern Bangladesh. *Bangladesh Agron. J*., 21(1): 1–7.

HOSSAIN, S. 2014. Sunflower farming trebles in Patuakhali. In: *The Daily Star*, 10 April 2014, Dhaka. P.7.

HUQ, N., HUGÉ, J., BOON, E. and GAIN, A. K. 2015. Climate change impacts in agricultural communities in rural areas of coastal Bangladesh: a tale of many stories. *Sustainability*, 7(7): 8437–8460.

HUSSAIN, M., FAROOQ, M., SHEHZAD, M., KHAN, M. B., WAHID, A. and SHABIR, G. 2012. Evaluating the performance of elite sunflower hybrids under saline conditions. *Int. J. Agric. Biol*, 14(1): 131–135.

ISAYENKOV, S. V. and MAATHUIS, F. J. M. 2019. Plant salinity stress: Many unanswered questions remain. *Frontiers in Plant Science*, 10: 80.

ISLAM, M., AFZAL, S., AHMAD, I., HAQ, A. and HUSSAIN, A. 2008. Salt tolerance among different sunflower genotype. *Sarhad J. Agri.*, 24(2): 242–250.

KATERJI, N., VAN HOORN, J. W., HAMDY, A. and MASTRORILLI, M. 2003. Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. *Agricultural water management*, 62(1): 37–66.

KHAN, E. A., QAISRANI S. A., HUSSAIN, N. and SADOZAI, G. U. 2012. Comparative study on the yield performance of sunflower hybrids under agro-ecological conditions of D. I. Khan. *Sarhad J. Agric.,* 28(2): 155–157.

KHATUN, M., TANVIR M. B. HOSSAIN, MONAYEM MIAH, M. A., KHANDOKER, S. and RASHID, M. A. 2016. Profitability of sunflower cultivation in some selected sites of Bangladesh. *Bangladesh J. Agril. Res.*, 41(4): 599–623.

KONUSKAN, D. B., ARSLAN, M. and OKSUZ, A. 2019. Physicochemical properties of cold pressed sunflower, peanut, rapeseed, mustard and olive oils grown in the Eastern Mediterranean region. *Saudi Journal of Biological Sciences*, 26(2): 340–344.

LI, W., ZHANG, H., ZENG, Y., XIANG, L., LEI, Z., HUANG, Q., LI, T., SHEN, F. and CHENG, Q. 2020. A Salt Tolerance Evaluation Method for Sunflower (*Helianthus annuus* L.) at the Seed Germination Stage. *Sci. Rep.*, 10(1): 10626. https://doi.org/10.1038/s41598-020-67210-3

MIAH, M. A. M. and MONDAL, M. R. I. 2017. Oilseeds sector of Bangladesh: Challenges and Opportunities. *SAARC J. Agri.*, 15(1): 161–172.

MIAH, M. A. M., RASHID, M. A. and SHIBLEE, S. A. M. 2014. *Assessment of socioeconomic impact of oilseed research and development in Bangladesh*. SPGR sub-project completion report, Project Implementation Unit (PIU), Bangladesh Agricultural Research Council (BARC), Dhaka.
MURAD, K. F. I., HOSSAIN, A., FAKIR, O. A., BISWAS, S. K., SARKER, K. K., RANNU, R. P. and TIMSINA, J. 2018. Conjunctive use of saline and fresh water increases the productivity of maize in saline coastal region of Bangladesh. *Agricultural Water Management*, 204: 262–270.
NARENDER, J., PADMAJA, J., SRINIVAS, A. and SAILAJA, V. 2017. Effect of Herbicides on Yield and Economics of Sunflower (*Helianthus annuus* L.). *International Journal of Pure & Applied Bioscience*, 5(4): 1582–1587.
PARVIN, G. A., ALI, M. H., FUJITA, K., ABEDIN, M. A., HABIBA, U. and SHAW, R. 2017. Land use change in southwestern coastal Bangladesh: consequence to food and water supply. In: *Land Use Management in Disaster Risk Reduction*. Springer, Japan, pp. 381–401.
RASHID, M. H., NASRIN, S. and MAHALDER, D. 2014. Zero tilled dibbled sunflower enables planting earlier and harvests more in the coastal saline area of Bangladesh. *Inter. J. Environ. Sci. Develop.*, 5(3): 260–264.
REHMAN, O. U. and HUSSAIN, M. K. 1998. Effect of salinity on growth and development of cultivated sunflower (*Helianthus annuus* L.). *Pakistan J. Sci.*, 50: 45–52.
SAS Institute Inc. 2017. JMP® 13 Design of Experiments Guide, Second Edition. Cary, NC: SAS Institute Inc.
TOLGA, E., LOKMAN, D. and ORTA, H. O. 2001. Water use characteristics of sunflower (*Helianthus annuus* L.) under deficit irrigation. *Pakistan J. of Biological Sciences*, 4(7): 766–769.
UNDP (UNITED NATIONS DEVELOPMENT PROGRAMME), FAO (FOOD AND AGRICULTURE ORGANIZATION). 1988. *Land resources appraisal of Bangladesh for agricultural development*. Report 2. Agricultural Regions of Bangladesh.
WANJARI, R. H., YADURAJ, N. T. and AHUJA, K. N. 2000. Critical period of weed competition in spring sunflower. *Indian J. Weed Sci.*, 32(1–2): 17–20.
ZHELJAZKOV, V. D., VICK, B. A., EBELHAR, M. W., BUEHRING, N., BALDWIN, B. S., ASTATKIE, T. and MILLE, J. F. 2008. Yield, oil content, and composition of sunflower grown at multiple locations in Mississippi. *Agron. J.*, 100(3): 635–639.

Contact information

Md. Atikur Rahman: atiksobari26@yahoo.com
Sharif Ahmed: s.ahmed@irri.org
Ferdousi Begum: bakul_bari@yahoo.com
Pryanka Roy: roypryanka@yahoo.com
Ahmed Gaber: a.gaber@tu.edu.sa
Akbar Hossain: akbarhossainwrc@gmail.com (corresponding author)