

## RESEARCH ARTICLE

## EARLY SOWING IMPROVES SEED YIELD OF SUNFLOWER GENOTYPES IN COASTAL SALINE SOIL

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## ARTICLE DETAILS

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## ABSTRACT

Soil salinity is a major constraint limiting crop production in the coastal regions of Bangladesh, where low cropping intensity persists due to saline intrusion and delayed planting after the Aman rice season. Sunflower (*Helianthus annuus* L.), a moderately salt-tolerant oilseed crop, offers potential to diversify cropping systems in this vulnerable ecosystem. This study aimed to identify the optimum sowing window and suitable sunflower genotype for enhancing yield performance in coastal saline soils. A two-year field experiment was conducted using a split-plot design with four sowing dates (15 December, 25 December, 4 January, 14 January) and four sunflower genotypes (BD-9389, BARI Sunflower-2, BARI Sunflower-3, Hysun-33) at Dacope, Khulna. Results revealed that early sowing on 15 December significantly improved growth parameters and yield across all genotypes compared to delayed sowing. The highest seed yield (2300.0 kg ha<sup>-1</sup>) and stalk yield (6.1 t ha<sup>-1</sup>) were recorded from Hysun-33 sown on 15 December, which also exhibited the largest head diameter (17.5 cm) and 1000-seed weight (60.0 g). Delayed sowing on 14 January led to substantial yield reduction, with BD-9389 producing the lowest seed yield (570.0 kg ha<sup>-1</sup>). The interactive effect of sowing date and genotype was significant for all measured traits including plant height, root length, leaf area index, and crop growth rate. Early sowing combined with salt-tolerant genotypes such as Hysun-33 can enhance sunflower productivity in saline-prone coastal areas of Bangladesh.

## KEYWORDS

Sunflower, sowing dates, coastal salinity, genotype performance, yield attributes

## 1. INTRODUCTION

Salinity-induced land degradation is an escalating problem for sustainable agriculture worldwide, particularly in coastal ecosystems where tidal inundation and soil salinization limit crop productivity (Paul et al., 2021; Rasel et al., 2013). In Bangladesh, nearly 1.05 million hectares of cultivable land in the southern coastal belt are exposed to varying levels of soil salinity, threatening food security and the livelihood of smallholder farmers (SRDI, 2010). This saline-prone region suffers from low cropping intensity—approximately 173% compared to the national average of 199% mainly because traditional long-duration Aman rice cultivars dominate the monsoon season and delay the planting of high-yielding rabi crops such as sunflower, wheat, and maize (BBS, 2011; Mondal et al., 2015). Moreover, limited access to freshwater and increasing soil salinity during the dry season further restrict cropping options, rendering vast land areas fallow and unproductive (Hasan et al., 2013; Rahman et al., 2015).

Sunflower (*Helianthus annuus* L.), globally ranked third among oilseed crops after soybean and rapeseed, offers considerable potential for cultivation in the coastal saline soils of Bangladesh due to its moderate tolerance to salinity and short-duration growth habit (Ali et al., 2004). Successful sunflower production in saline regions depends heavily on

optimal sowing time and the selection of salt-tolerant genotypes, as these factors influence germination, crop establishment, growth, and final seed yield (Baghdadi et al., 2014; Abdou et al., 2011). Early sowing ensures that critical growth stages—especially flowering and grain filling—coincide with periods of lower soil salinity, thus enhancing physiological performance and yield attributes such as head diameter, seed number, and 1000-seed weight (Ozturk et al., 2017; Ahmed et al., 2015). Conversely, delayed sowing increases exposure to high salinity and terminal drought stress, leading to reduced photosynthetic efficiency, impaired reproductive development, and lower seed yield (Rahnama and Bakhshandeh, 2005; Erdogan et al., 2017).

Although previous studies have reported the effects of sowing dates and salinity on sunflower performance, significant research gaps remain (Ali et al., 2004; Allam et al., 2003; Baghdadi et al., 2014; Ozturk et al., 2017). First, integrated field-level assessments combining genotype screening and sowing date optimization under natural salinity conditions are scarce. Second, there is a lack of experimental evidence from the unique agro-ecological setting of southwestern Bangladesh, where tidal floodplain soils (AEZ-13) and progressive dry-season salinity complicate crop establishment (Paul et al., 2021). Third, recent high-yielding and salt-tolerant sunflower genotypes such as Hysun-33 and BARI Sunflower-2 have not been extensively evaluated under multi-sowing date

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treatments in this region. Furthermore, limited studies have captured multi-year seasonal variations to confirm the consistency of genotype performance under field salinity stress. Lastly, relationships between physiological traits (leaf area index, crop growth rate, root length) and yield outcomes remain underexplored in saline-prone agro-ecosystems.

The challenges of this research lie in addressing the fluctuating nature of coastal salinity, variations in microclimate, and genotype-environment interactions that affect sunflower performance. Effective field experimentation is needed to resolve uncertainties regarding optimum sowing windows that minimize salt stress during reproductive stages. Genotype-dependent salinity tolerance mechanisms, such as osmotic adjustment and root development, must be correlated with yield traits to identify superior cultivars for saline environments. Moreover, multi-year trials are essential to account for annual climatic variability, ensuring the reliability and applicability of research outcomes in farmers' fields. Overcoming these challenges requires the deployment of robust experimental designs that integrate genotype evaluation and sowing time determination under real saline field conditions.

This study holds substantial significance as it provides the first comprehensive, two-year field-based evaluation of sowing dates and sunflower genotypes in the coastal saline soils of southern Bangladesh. The findings will enable evidence-based recommendations for agronomic management practices aimed at enhancing cropping intensity and oilseed production in this vulnerable region. The outcomes are expected to contribute to national strategies for climate-resilient agriculture, ensuring sustainable utilization of underexploited saline lands and reducing dependence on fallow periods during the dry season.

The novelty of this research lies in its integrated approach to optimizing both sowing date and genotype selection for sunflower production in natural coastal saline conditions—a research area insufficiently addressed in previous agronomic studies. The work also provides physiological and morphological insights critical for the development of climate-resilient cropping systems in the coastal agro-ecosystems of Bangladesh.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Soil Characteristics

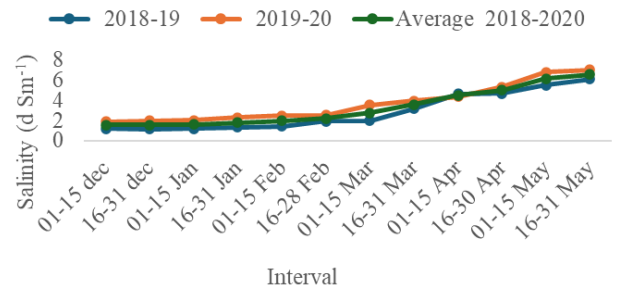
A two-year field experiment was conducted during the rabi seasons of 2019-20 and 2020-21 at Dacope, Khulna ( $22^{\circ}34'N$ ,  $88^{\circ}30'E$ ), located in the Ganges Tidal Floodplain (Agro-Ecological Zone 13) of southwestern Bangladesh. The site is representative of coastal saline soils, characterized by silty clay texture and moderate salinity levels ( $4.0$ – $6.5$   $dS\ m^{-1}$ ) during the dry season. Pre-sowing soil analysis showed pH 7.2, organic matter 1.04%, and total nitrogen 0.07%. Rainfall, temperature, and salinity data during the crop period were recorded (Figure 1 and 2) following standard meteorological procedures (BARI, 2017).



**Figure 1:** Map showing the experimental site of Dacope, Khulna



**Figure 2:** Line graph showing monthly cumulative average (2019-20 and 2020-21) rainfall (mm) of the experimental site of Dacope, Khulna.



**Figure 3:** Monthly average salinity ( $dS\ m^{-1}$ ) level of the experimental field soil during 2019-20 and 2020-21.

### 2.2 Experimental Design and Treatments

The study was laid out in a split-plot arrangement within a randomized complete block design (RCBD) with three replications. The main plot factor comprised four sowing dates: 15 December ( $S_1$ ), 25 December ( $S_2$ ), 4 January ( $S_3$ ), and 14 January ( $S_4$ ). The subplot factor included four sunflower genotypes: BD-9389 ( $V_1$ ), BARI Sunflower-2 ( $V_2$ ), BARI Sunflower-3 ( $V_3$ ), and Hysun-33 ( $V_4$ ). Each plot measured  $4\ m \times 3\ m$ , with 1 m buffer zones between adjacent plots.

### 2.3 Crop Management Practices

Seeds were sown by dibbling method at 30 cm plant-to-plant and 60 cm row-to-row spacing, following recommended agronomic practices (FRG, 2018). Fertilizer doses were applied at  $120:60:80\ kg\ ha^{-1}$  of N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O, using urea, triple superphosphate (TSP), and muriate of potash (MoP) respectively. Half the nitrogen and all phosphorus and potassium were applied at final land preparation; the remaining nitrogen was top-dressed at 30 DAS. Irrigation, weeding, pest management, and other cultural operations were uniformly practiced across all treatments to ensure consistency.

### 2.4 Data Collection

Growth and physiological parameters such as plant height (cm), root length (cm), leaf area index (LAI), and crop growth rate (CGR) were recorded at 30, 45, 60, 75 days after sowing (DAS), and at harvest. LAI was calculated following the method described, while CGR was determined using the formula outlined by (Hunt, 1982; Watson, 1952). Yield and yield components including head diameter (cm), number of filled seeds per head, 1000-seed weight (g), seed yield ( $kg\ ha^{-1}$ ), and stalk yield ( $t\ ha^{-1}$ ) were measured from ten randomly selected plants per plot. Final yield data were adjusted to 12% moisture content.

### 2.5 Statistical Analysis

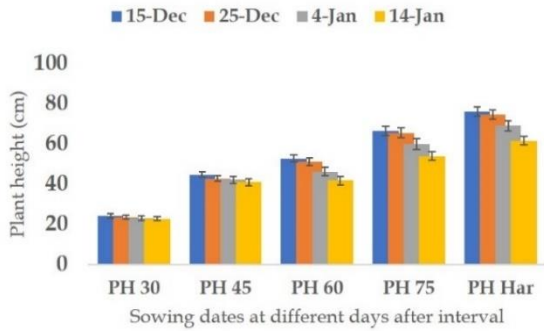
All collected data were subjected to analysis of variance (ANOVA) using Statistix 10 software (Analytical Software, USA). Treatment means were compared using Least Significant Difference (LSD) at the 5% probability level ( $p \leq 0.05$ ) (Gomez and Gomez, 1984). Year-wise and pooled analyses were performed to examine the consistency of treatment effects across seasons.

## 3. RESULTS

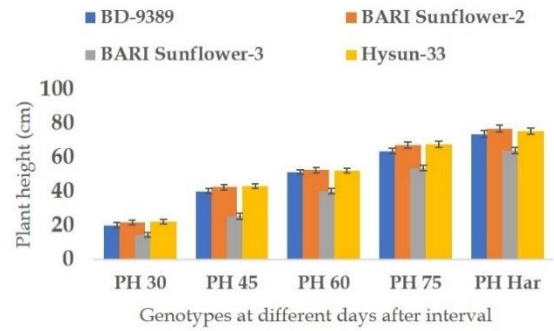
### 3.1. Growth and Phenological Attributes

#### 3.1.1. Plant Height (cm)

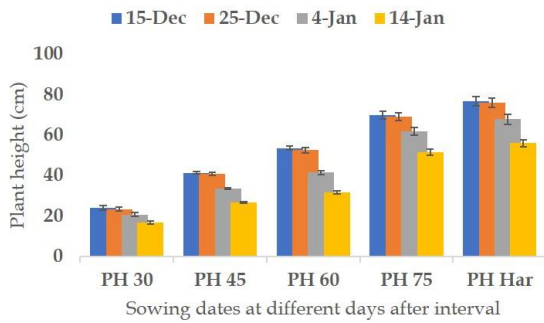
Plant height was significantly influenced ( $p \leq 0.01$ ) by sowing dates, genotypes, and their interactions in both cropping seasons. Early sowing (15 December) resulted in the tallest plants, with the genotype Hysun-33 attaining maximum heights of 135.8 cm in 2019-20 and 138.2 cm in 2020-21. This enhanced vertical growth is likely due to favourable soil moisture availability and reduced salinity stress during the vegetative stage. Conversely, plants sown on 14 January recorded significantly shorter heights, particularly in genotype BD-9389 (92.5 cm and 93.8 cm), due to higher salinity stress in the latter part of the season, which restricted cell expansion and elongation.



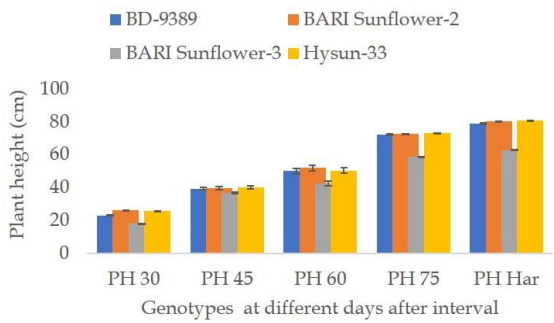
**Figure 4(a):** Effect of sowing dates on plant height (cm) during 2019-20



**Figure 5(a):** Effect of genotypes on plant height (cm) during 2019-20



**Figure 4(b):** Effect of sowing dates on plant height (cm) during 2020-21

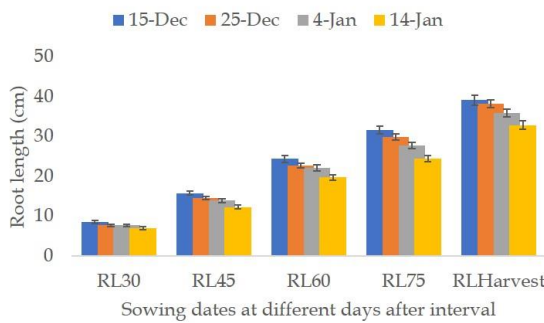


**Figure 5(b):** Effect of genotypes on plant height (cm) during 2020-21

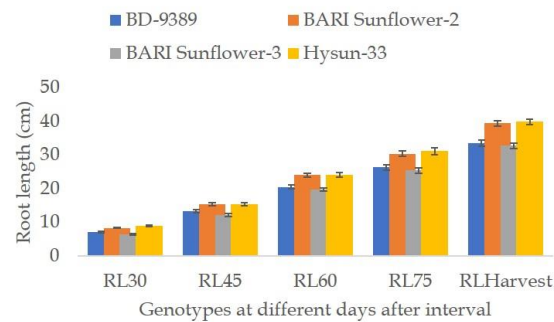
### 3.1.2 Root Length (cm)

Root length was also significantly affected by sowing time, genotype, and their interaction ( $p \leq 0.01$ ). The longest roots were measured in Hysun-33 under early sowing (27.4 cm and 28.3 cm), while BD-9389 under the latest sowing date exhibited the shortest roots (18.1 cm and 18.7 cm).

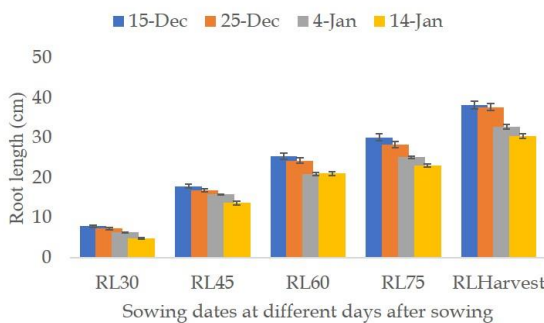
Early sowing enabled deeper root penetration and enhanced soil exploration, crucial under saline conditions for better water and nutrient uptake. The reduction in root length in late-sown plants can be attributed to increased soil osmotic stress and reduced metabolic activity during critical root development phases.



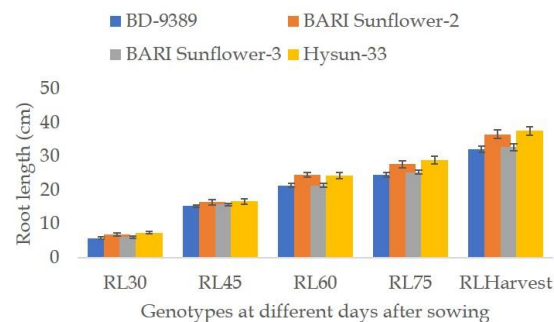
**Figure 8(a):** Effect of sowing dates on root length (cm) during 2018-19



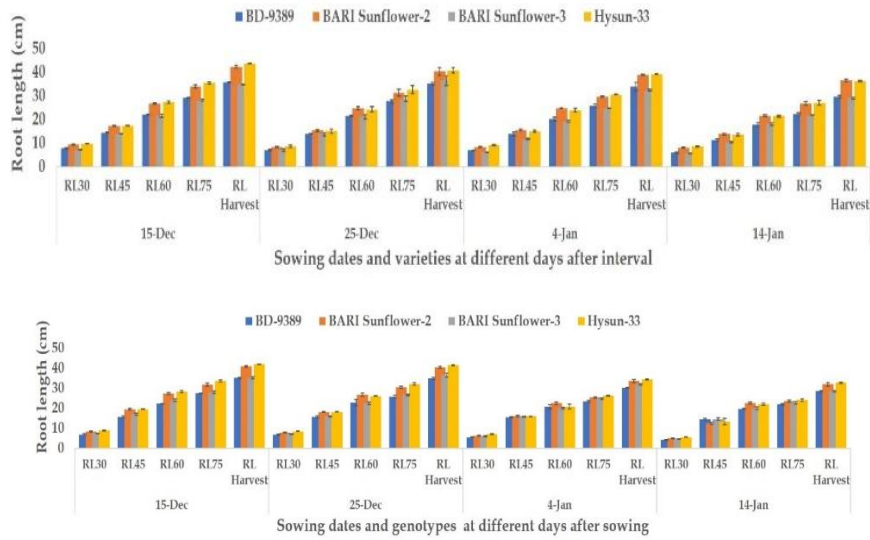
**Figure 9(a):** Effect of genotypes on root length (cm) during 2019-20



**Figure 8(b):** Effect of sowing dates on root length (cm) during 2019-20



**Figure 9(b):** Effect of genotypes on root length (cm) during 2020-21

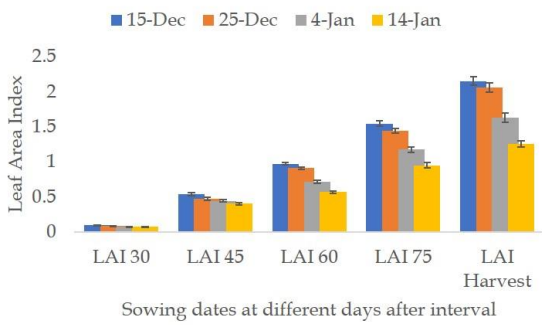


**Figure 11:** Interaction effect of sowing dates and genotypes on root length (cm) during 2019-20 (A) and 2020-21 (B) growing season.

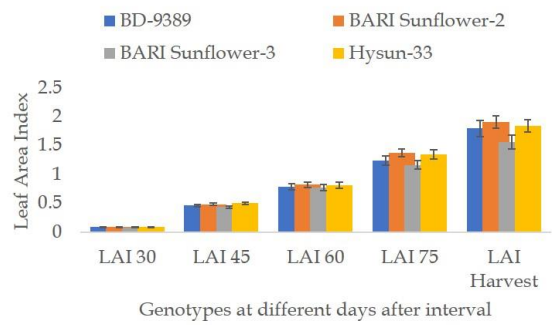
**3.1.3 Leaf Area Index (LAI)**

LAI, a vital indicator of canopy development, was significantly influenced ( $p \leq 0.01$ ) by all factors and their interactions. Maximum LAI (5.45 and

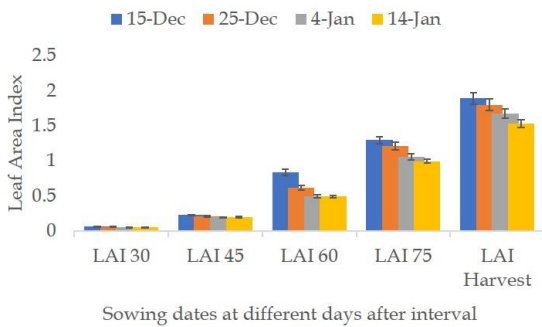
5.62 at 75 DAS) was recorded in Hysun-33 sown on 15 December, indicating superior leaf expansion and assimilation potential. In contrast, BD-9389 exhibited the lowest LAI values under late sowing (14 January), likely due to salinity-mediated inhibition of leaf expansion.



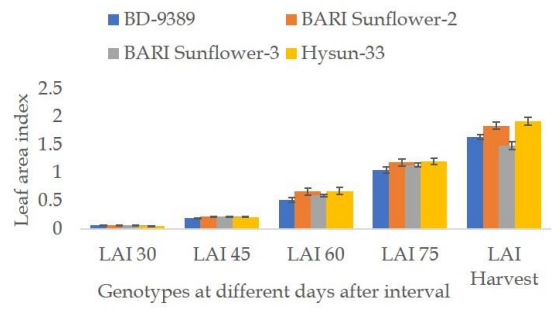
**Figure 12(a):** Effect of sowing dates on leaf area index during 2019-20



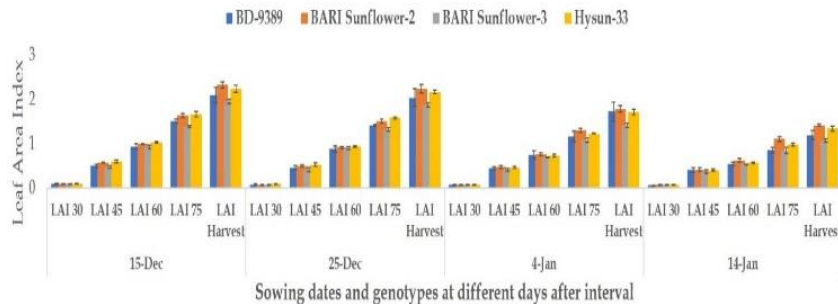
**Figure 13(a):** Effect of genotypes on leaf area index during 2019-20



**Figure 12(b):** Effect of sowing dates on leaf area index during 2020-21



**Figure 13(b):** Effect of genotypes on leaf area index during 2020-21

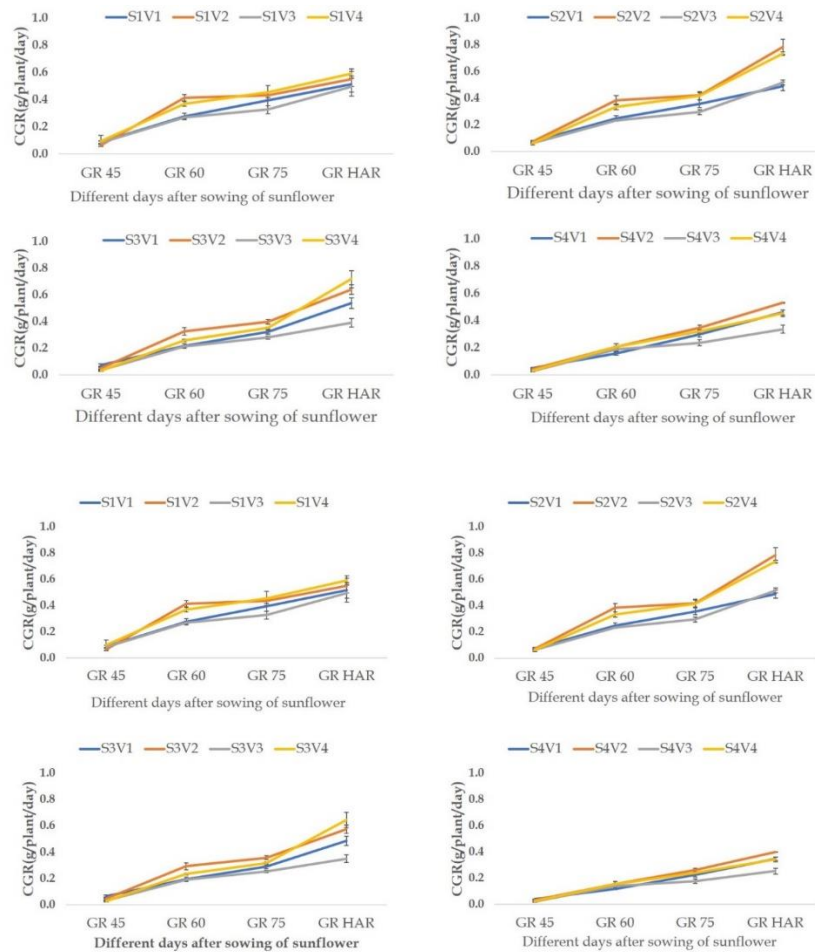


**Figure 15:** Interaction of sowing dates and genotypes on leaf area index during 2019-20 (A) and 2020-21 (B) growing season.

### 3.1.4. Crop Growth Rate (CGR)

CGR demonstrated significant variation across treatments, with the highest CGR values observed in Hysun-33 under the earliest sowing date during both vegetative and reproductive phases. Delayed sowing

progressively reduced CGR across all genotypes, likely due to salinity stress and shortened growth duration. The superior CGR of Hysun-33 under early sowing underscores its capacity to maintain photosynthetic productivity and biomass accumulation in saline environments.



**Figure 17:** Interaction effect of sowing date and genotypes on crop growth rate during 2019-20 (A-D) and 2020-21 (E-H)

## 3.2. Yield and Yield Components

### 3.2.1 Number of Effective Grains per Head

The number of effective grains per head was significantly affected by sowing date, genotype, and their interaction ( $p \leq 0.01$ ). The highest values were recorded in Hysun-33 under 15 December sowing (513.2 and 697.0), while BD-9389 under 14 January sowing produced the lowest grain numbers (155.0 and 180.3). Early sowing extended the reproductive phase and ensured favourable environmental conditions for effective pollination and fertilization, resulting in improved grain set.

### 3.2.2 Head Diameter (cm)

Head diameter varied significantly ( $p \leq 0.01$ ) among treatments, with Hysun-33 attaining the largest head sizes (17.5 cm and 16.1 cm) under early sowing. In contrast, BARI Sunflower-3 exhibited the smallest head diameters (8.1 cm and 8.0 cm) under late sowing. The superior sink capacity of Hysun-33 under early sowing is attributed to optimal resource allocation during the critical head development phase.

### 3.2.3 Total Grains per Plant

Total grain count per plant was significantly influenced ( $p \leq 0.01$ ) by the main and interaction effects. Hysun-33 produced the maximum total grains (1122.9 and 1002.0) when sown on 15 December, whereas BD-9389 under the latest sowing recorded the minimum grain counts (115.7 and 336.6). The improved grain number in early sowing treatments can be linked to reduced exposure to terminal salinity stress, which adversely impacts reproductive development.

### 3.2.4 1000-Grain Weight (g)

Thousand-grain weight showed notable differences across treatments,

being highest (60.0 g and 62.0 g) in Hysun-33 sown on 15 December. The lowest 1000-grain weight was observed in BD-9389 sown on 14 January (46.6 g and 27.6 g).

### 3.2.5 Seed Yield ( $\text{kg ha}^{-1}$ )

Grain yield was significantly influenced ( $p \leq 0.01$ ) by sowing date, genotype, and their interaction. The highest grain yield was achieved by Hysun-33 sown on 15 December (2256  $\text{kg ha}^{-1}$  and 2300  $\text{kg ha}^{-1}$ ), surpassing all other genotype and sowing time combinations. Conversely, BD-9389 under the 14 January sowing produced the lowest yields (466.7  $\text{kg ha}^{-1}$  and 570  $\text{kg ha}^{-1}$ ). Early sowing ensured better establishment, vegetative growth, and reproductive success, all contributing to enhanced final yield.

### 3.2.6 Stover Yield ( $\text{t ha}^{-1}$ )

Stover yield followed a similar pattern to grain yield, being highest in Hysun-33 under early sowing (6.0  $\text{t ha}^{-1}$  and 6.1  $\text{t ha}^{-1}$ ). The lowest stover yields were recorded in BD-9389 under the latest sowing date (2.4  $\text{t ha}^{-1}$  and 1.9  $\text{t ha}^{-1}$ ). This emphasizes that early sowing supports overall biomass production, essential for both grain and stover yield, under saline-prone environments.

## 3.3 Interaction Effects

A highly significant interaction effect between sowing date and genotype ( $p \leq 0.01$ ) was evident for all measured traits. The combination of early sowing (15 December) with Hysun-33 consistently resulted in superior performance across growth, phenology, yield attributes, and final productivity. This interaction underscores the importance of synchronizing genotype selection with optimal sowing windows to maximize sunflower performance in saline agro-ecosystems.

**Table 1:** Effect of sowing dates on yield attributes of sunflower genotypes grown in natural salinity affected areas of Daccoppe, Khulna during rabi season of 2019-20 and 2020-21

Sowing time	Filled seed head <sup>-1</sup>	Head diameter (cm)	Total grains plant <sup>-1</sup>	1000-seed weight (g)	Seed yield (kg ha <sup>-1</sup> )	Stover yield (tha <sup>-1</sup> )	Filled seed head <sup>-1</sup>	Head diameter (cm)	Total grains plant <sup>-1</sup>	1000-seed weight (g)	Seed yield (kg ha <sup>-1</sup> )	Stover yield (tha <sup>-1</sup> )
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21		2019-20	2020-21	2019-20	2020-21	2019-20
15-Dec	419.4a	571.0a	15.9a	15.2a	730.4a	875.8a	15-Dec	419.4a	571.0a	15.9a	15.2a	730.4a
25-Dec	393.3a	541.5a	15.3a	14.9a	612.2a	846.5a	25-Dec	393.3a	541.5a	15.3a	14.9a	612.2a
4-Jan	333.2a	392.9b	12.7b	12.0b	424.9b	629.6b	4-Jan	333.2a	392.9b	12.7b	12.0b	424.9b
14-Jan	224.3b	271.5c	8.8c	8.7c	217.3c	454.6c	14-Jan	224.3b	271.5c	8.8c	8.7c	217.3c
CV	35.97	14.24	5.54	6.32	33.95	13.27	CV	35.97	14.24	5.54	6.32	33.95
Level of Sig.	**	**	**	**	**	**	Level of Sig.	**	**	**	**	**

**Table 2:** Effect of genotypes on yield attributes of sunflower grown in natural salinity affected areas of Daccoppe, Khulna during rabi season of 2019-20 and 2020-21

Genotype	Effective grain plant <sup>-1</sup>		Head diameter (cm)		Number of total grains plant <sup>-1</sup>		1000-grain weight (g)		Yield (kg ha <sup>-1</sup> )		Stalk yield (tha <sup>-1</sup> )	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
BD-9389	271.0c	345.6c	12.9b	12.8b	333.5b	589.7c	49.5d	43.8b	899.2c	924.2d	3.4c	3.1c
BARI Sunflower-2	379.4a b	498.5 b	13.9a	13.1a b	578.4a	762.9b	55.0b	52.3a	1332.5 b	1361.2 b	4.1b	3.9b
BARI Sunflower-3	307.1 bc	350.7c	11.6c	11.4c	389.9b	593.4c	50.6c	44.8b	925.0c	995.4c	3.4c	3.2c
Hysun-33	412.7a	582.0 a	14.2a	13.5a	683.0a	860.5a	56.3a	55.8a	1548.3 a	1743.0 a	4.6a	4.9a
CV	35.97	14.24	5.54	6.32	33.95	13.27	2.1	13.53	3.16	2.43	6.55	3.72
Level of Sig.	*	**	**	**	**	**	**	**	**	**	**	**

**Table 3:** Interaction effect of sowing dates and genotypes on yield attributes of sunflower grown in natural salinity-affected areas of Daccoppe, Khulna during rabi season of 2019-20 and 2020-21

Interaction		Filled seed head <sup>-1</sup>		Head diameter (cm)		Number of total grains plant <sup>-1</sup>		100-seed weight (g)		Seed yield (kg ha <sup>-1</sup> )		Stover yield (t ha <sup>-1</sup> )	
Sowing time	Genotype	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
15-Dec	BD-9389	341.9a -e	484.3 b	15.7bc	15.6a	473.8de	789.3bcd	52.0bc	55.3ab	1186. 7e	1235. 0g	3.9c	4.1e
	BARI Sunflower-2	471.3a bc	631.6a	16.9ab	15.4a	837.4b	936.0ab	59.3a	61.3a	1780. 0b	1861. 7c	4.8b	4.9c
	BARI Sunflower-3	333.2a -e	471.0 bc	13.5de	13.6b	487.8de	776.0cd	53.3b	57.3ab	1275. 0d	1308. 3f	4.1c	4.2e
	Hysun-33	531.2a	697.0a	17.5a	16.1a	1122.9a	1002.0a	60.0a	62.0a	2256. 0a	2300. 0a	6.0a	6.1a
25-Dec	BD-9389	319.0 b-e	458.0 bc	15.1c	15.3a	449.4de	763.0cd	51.0cd	54.6ab	1161. 7e	1073. 3i	3.9c	3.7f
	BARI Sunflower-2	443.7a -d	600.0a	16.6ab	15.1a	791.4bc	905.0abc	58.6a	60.6a	1735. 0bc	1708. 3d	4.7b	4.6d
	BARI Sunflower-3	313.0 b-e	448.0 bc	13.0de	13.3b	393.1def	753.0cd	52.0bc	56.6ab	1060f	1181. 7h	3.4de	3.8f
	Hysun-33	497.4a b	660.0a	16.8ab	15.8a	817.0bc	965.0a	59.6a	61.6a	1691. 7c	2120b	5.0b	5.7b
4-Jan	BD-9389	268.0c de	260.0f gh	12.3ef	11.5cd	297.5def	470.3fg	49.3d	37.6cd	781.7 hi	818.3 k	3.2ef	2.8h
	BARI Sunflower-2	350.6a -e	428.0 bcd	13.2de	12.5bc	432.3de	663.7de	52.6bc	46.3bc	1065. 0f	1025. 0i	3.9c	3.6f

**Table 3(Cont.):** Interaction effect of sowing dates and genotypes on yield attributes of sunflower grown in natural salinity-affected areas of Dacope, Khulna during rabi season of 2019-20 and 2020-21

	BARI Sunflower-3	406.8a-d	286.3e fg	11.7f	10.9d	543.7cd	489.0fg	50.0d	37.0cd	840.0h	871.6j	3.4def	2.9h
	Hysun-33	307.5b-e	597.3a	13.6d	13.0b	426.2de	895.7abc	53.3b	59.3a	1288.3d	1411.7e	3.8cd	4.6d
14-Jan	BD-9389	155.0e	180.3h	8.7gh	8.6ef	115.7f	336.3g	46.6e	27.6d	466.7j	570.0l	2.4g	1.9j
	BARI Sunflower-2	252.0de	334.6def	9.4g	9.3e	252.5ef	547.0ef	49.6d	41.0c	750.0i	850.0jk	3.0f	2.5i
	BARI Sunflower-3	175.3e	197.6gh	8.1h	8.0f	135.2f	355.7g	47.3e	28.3d	525.0j	620.0l	2.5g	2.0j
	Hysun-33	314.7b-e	373.6cde	8.9gh	9.1ef	366.1def	579.7ef	52.3bc	40.3c	956.7g	1140.0h	3.6cd	3.3g
CV		35.97	14.24	5.54	6.32	33.95	13.27	2.1	13.53	3.16	2.43	6.55	3.72
Level of Sig.		*	*	*	*	*	*	*	*	**	**	**	**

Here, CV indicates coefficient of variation; \*, \*\* indicate significant at 5% and 1% level. Values in a column having similar letter means statistically similar while dissimilar means statistically differ.

## 5. DISCUSSIONS

The present study demonstrated that both sowing date and genotype selection exerted significant influence on the growth, physiological attributes, and yield performance of sunflower under natural coastal saline conditions of southwestern Bangladesh. The findings are consistent with prior reports indicating that early sowing optimizes crop establishment and productivity by mitigating exposure to escalating soil salinity during the late rabi season (Paul et al., 2021; Rasel et al., 2013).

Early sowing (15 December) resulted in superior performance across multiple traits including plant height, root length, leaf area index (LAI), crop growth rate (CGR), and key yield components such as head diameter, number of filled grains per head, 1000-seed weight, and final seed yield. These improvements likely stem from the crop's escape from peak dry-season salinity and associated physiological stress, thereby facilitating optimal resource utilization during the vegetative and reproductive phases (Baghdadi et al., 2014; Ozturk et al., 2017). Similar benefits of early planting have been documented for sunflower and other rabi crops in salinity-affected environments (Ali et al., 2004; Ahmed et al., 2015).

Delayed sowing (14 January), conversely, markedly reduced growth vigor, LAI, and CGR, reflecting compromised photosynthetic capacity and limited biomass accumulation (Kader et al., 2006). The decline in reproductive traits—including smaller head diameter, reduced grain number, and lower seed weight—can be attributed to the cumulative effects of late-season salinity stress, which disrupts pollen viability, fertilization, and grain filling (Rahnama and Bakhshandeh, 2005; Erdogan et al., 2017). This pattern underscores the necessity of timely sowing to avoid the critical threshold period when soil salinity and osmotic stress peak in coastal soils.

The study also confirmed significant genotypic variation in salinity tolerance, with Hysun-33 consistently outperforming other genotypes across all growth stages and yield attributes. This superior performance suggests inherent physiological mechanisms such as effective osmotic adjustment, deeper rooting ability, and efficient photosynthate partitioning that enable Hysun-33 to maintain metabolic activity under saline stress (Erdogan et al., 2017; Paul et al., 2021). Conversely, BD-9389 displayed poor adaptability, possibly due to its limited salinity tolerance and reduced growth plasticity.

The significant genotype × sowing date interactions further reinforce the need for integrated management strategies combining early sowing with salt-tolerant genotypes to achieve yield stability under coastal saline conditions (Rashid et al., 2014). Specifically, the findings suggest that early-sown Hysun-33 is the best-fit technology package for maximizing sunflower productivity in this environment—a conclusion in line with regional studies emphasizing genotype-specific salinity responses (Mondal et al., 2015; Rahman et al., 2015).

Importantly, this study fills a critical knowledge gap in the context of multi-year, field-based evaluation of sunflower in the AEZ-13 agro-ecological zone, where limited prior research has systematically

addressed the interactive effects of sowing time and genotype under fluctuating salinity conditions. The consistency of the results across two cropping seasons validates the robustness of the findings and their potential for practical recommendations in coastal agriculture.

Moreover, the positive correlation observed between physiological traits (e.g., LAI, CGR) and yield outcomes emphasizes the importance of maintaining canopy development and growth rates to ensure reproductive success under salinity stress (Watson, 1952; Hunt, 1982). These physiological insights are valuable for breeding programs targeting stress-adaptive traits for saline environments.

## 6. CONCLUSION

The present study clearly demonstrates that both sowing date and genotype selection play crucial roles in optimizing sunflower growth and yield under coastal saline soil conditions. Early sowing, particularly on 15 December, significantly enhanced plant height, root development, leaf area index, and crop growth rate, leading to improved yield components and overall productivity. Among the genotypes evaluated, Hysun-33 consistently outperformed others across all parameters, indicating its superior adaptability and tolerance to saline stress. BARI Sunflower-2 also showed considerable potential under early sowing conditions.

Delayed sowing beyond early January substantially reduced growth vigor, reproductive efficiency, and seed yield, likely due to increased soil salinity and shortened growth duration. These findings highlight the importance of adjusting planting schedules and selecting salt-tolerant genotypes to maximize the use of the coastal ecosystem's limited productivity window.

Therefore, for successful sunflower cultivation in the saline-prone regions of Bangladesh and similar agro-ecological zones, early sowing combined with the use of tolerant genotypes such as Hysun-33 is recommended. This integrated approach can contribute to enhanced oilseed production, improved land use efficiency during the dry season, and increased farmer profitability in saline-affected coastal belts.

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