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Research Article

# Productivity of Zero-Tilled Dibbled Sunflower under Different Planting Densities in Salt Affected Soils of Bangladesh

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## Abstract

Planting density is an important factor for enhancing the productivity and profitability of sunflower in saline ecosystems which has not been sufficiently evaluated in farmers' fields of diverse saline soils. An on-farm experiment was conducted to identify the suitable planting density for better growth and higher yield and profit in the saline soil. The experiment was conducted in three salt affected sites with three planting densities, 29630, 37037 and 74074 ha$^{-1}$ through the planting arrangement of 75 cm × 45 cm, 60 cm × 45 cm and 45 cm × 30 cm, respectively, under zero tilled condition with four replications. Results revealed that seed yield obtained in planting arrangement, 60 cm × 45 cm and 45 cm × 30 cm were 31.3 % and 22.2 % higher than 75 cm × 45 cm, respectively. The locations with salinity of 6.02 and 7.71 dS m$^{-1}$ decreased seed yield by 6.5 % and 17.4 %, respectively, compared to 4.93 dS m$^{-1}$. The planting arrangement, 60 cm × 45 cm increased the gross margin by 35-50 % due to higher seed yield against slightly higher cost for seed and a greater number of labors required for different operations but decreased by 24-49 % in 45 cm × 30 cm where seed and labor requirement was the highest among treatments. The adoption of planting arrangement, 60 cm × 45 cm can increase the productivity of zero-tilled dibbled sunflower and thus increase the income of coastal saline farmers.

**Keywords:** Plant population, saline soil, sunflower, yield and profitability

## Introduction

Over 800 million hectares of land globally affected by salt contamination, including 77 million hectares of irrigated land (FAO, 2008; Eynard et al., 2005). In Bangladesh

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coastal saline areas have expanded from 0.83 million to 1.09 million hectares due to climate change, leaving large areas uncultivable (Karim et al., 1990; SRDI, 2012). Across South and Southeast Asia, millions of hectares lie fallow due to salinity, with about 0.33 million hectares left uncultivated in Bangladesh during the winter season (Rashid et al., 2018; Ibrahim et al., 2018; Shahidullah et al., 2018). Cultivating salt-tolerant oilseed crops during these fallow periods could significantly improve land productivity (Rashid et al., 2015).

Bangladesh currently experiences a per capita oil consumption deficit, with domestic intake at only 10 grams per day compared to the recommended 22 grams (Rahman and Khan, 2005). Closing this gap requires enhancing domestic oilseed production, either through technological advancements or the introduction of high-yielding oilseed crops. Sunflower presents a viable solution due to its high-quality edible oil, adaptability to diverse environments, low labor demands, and compatibility with mechanization, establishing it as a major oilseed crop worldwide (Ali et al., 2013; Ozer et al., 2004; Kazemeini et al., 2009). Research indicates that rice-sunflower cropping systems are well suited for coastal saline regions, which could contribute to increase national oil consumption (Rashid et al., 2013).

Single wet season rice is the predominant cropping system in the saline coastal area of Bangladesh. The slow drying process of excessive moist soil after the harvest of wet season rice delays the field to come in field condition to plough land for dry season winter (rabi) and pre-monsoon crops. Again, the delayed planting of winter crops such as sunflowers decreases yield due to warmer temperatures at the early growth period, which promotes excessive early stem growth and reduces time to flowering. Moreover, the delayed-planted crop is often affected by the storm surges and rainfall at reproductive and maturity stages. The zero-till dibbled sunflower in residual moist soil can overcome this worse situation and harvest a higher seed yield and boost income through minimizing cost for land preparation and irrigation (Rashid et al., 2014).

Salinity is a major environmental constraint that hampers plant growth and yield, including that of sunflower (Majeed et al., 2010; Khan et al., 2014; Abd_Allah et al., 2015; Munns and Tester, 2008; Rozema and Flowers, 2008; Kronzucker and Britto, 2011; Zhang and Shi, 2013). Sunflower exhibits moderate sensitivity to salinity (Hafeez et al., 2017; Katarji et al., 2003), with high salinity levels markedly reducing seed yield (Zeng et al., 2015). However, agronomic strategies such as early sowing, selection of hybrid varieties, and optimization of planting density can help alleviate the negative impacts of salinity on sunflower productivity (Rashid et al., 2014; Ishfaq et al., 2009; Ali et al., 2011).

Planting density, managed by adjusting row and plant spacing, is essential for optimizing sunflower yield, as sunflower cannot compensate for interspace gaps through branching or tillering (Pereira and Hall, 2019). Achieving the ideal plant density maximizes resource efficiency and promotes balanced crop growth (Pereira and Hall, 2019). Studies indicates that adjustments in row and plant spacing affect root distribution and soil moisture levels (Cucci et al., 2017). Higher plant densities, however, increase competition for light, reducing both vegetative and reproductive adaptability (Soleymani, 2017) while lower densities limit light absorption and decrease yield per unit area (Kemanian et al., 2004; Ali et al., 2013).

The influence of plant density on grain yield and profitability can vary across salinity gradients in zero-till dibbled planting systems. Therefore, an on-farm experiment was conducted in a tidal saline ecosystem to evaluate the effects of plant density on sunflower yield and profitability under zero-till dibbled conditions.

## Materials and Methods

### Experimental Site and Season

The on-farm trial was conducted during the dry season in the villages of Shadpur and Bharasimla in Kaligonj Upazila, and Shreefalkathi in Shamnagar Upazila, Satkhira district, Bangladesh. These locations lie within the Ganges Tidal Flood Plain agro-ecological zone (UNDP and FAO, 1988). The climate is subtropical, with an average annual rainfall of 1710 mm, peaking in July and August. Mean temperatures range from a minimum of is 12.5°C in January to a maximum of 35.5°C in April and May. The soil in the experimental fields, up to 15 cm depth, is clay loam with a pH of 7.4 to 7.7 (1:2.5 with water). Organic carbon content is 9.5 - 10.8 g $kg^{-1}$ (Walkley and Black method; Allison, 1965), total nitrogen 0.9- 1.1 g $kg^{-1}$ (Yoshida et al., 1976), available phosphorus 26.7- 29.7 mg $kg^{-1}$ (Olsen et al., 1982), exchangeable potassium 0.4 -0.6 m mol $kg^{-1}$ (Page et al., 1982), available sulphur 25.7- 26.3 mg $kg^{-1}$ (Fox et al., 1964), and extractable zinc 0.9 -1.0 mg $kg^{-1}$ (Page et al., 1982).

### Experimental Design and Treatments

The field experiment employed a randomized complete block design with four replications with each plot covering an area of 40 $m^2$. The experimental fields had similar soil types and crop management histories. Three planting densities were tested: (a) 74074 plants $ha^{-1}$ with 45 cm row spacing and 30 cm plant spacing, (b) 37037 plants $ha^{-1}$ with 60 cm row spacing and 45 cm plant spacing, and (c) 29630 plants $ha^{-1}$ with 75 cm row spacing and 45 cm plant spacing. The third density reflects the current standard practice (Rashid et al., 2012), while the other two densities were selected in consultation with experienced farmers who adopted zero-till dibbled sunflower after the monsoon rice harvest.

### Crop Establishment

Sunflower was grown during the dry season (November to March). After harvesting the monsoon rice, sunflower seeds were manually dibbled under zero-till conditions. The hybrid cultivar Hysun33 was used, with two seeds per hill dibbled according to the designated treatments between November 22 and 24. Plant emergence occurred within five days of sowing, and thinning to one plant per hill was carried out 15 days after sowing. The crop reached maturity by March 7, and harvesting took place between March 7 and 10. Fertilizers were applied at the following rates of 90 kg N, 40 kg P, 97 kg K, 30 kg S, 5 kg Zn, and 1.4 kg B per hectare as per recommendation of the fertilizer recommendation guide (Ahmmed et al., 2018). Phosphorus was applied as triple superphosphate, potassium as KCl, sulphur as gypsum, zinc as zinc sulphate, and boron as boric acid. Half of the nitrogen was applied as urea at 15 days after plant emergence, while the remaining nitrogen applied in two equal splits at 40-42 and 62-64 days after sowing. Irrigation was provided three times at early vegetative, bud formation and seed development stages (24-25, 40-42, and 62-64 days after sowing, respectively) with irrigation water electrical conductivities of 1.05-1.20, 1.21-1.71, and 1.67-2.78 dS $m^{-1}$ at the Shadpur, Bharasimla, and Shreefalkathi sites, respectively. The zero-till crop was established with the residual soil moisture and this early sown crop. The other two irrigation was applied at two critical stages of sunflower.

## Monitoring and Measurement

### Soil Salinity

Electrical conductivity (EC) of the topsoil (0-15 cm) in the unit plots of all experimental sites was measured using a 1:5 soil: water suspension (EC 1:5). The EC values were then converted to soil saturation extract EC (ECe) following the method outlined by Watling (2007).

### Seed Yield

Seed yields were measured from a 20.25 $m^2$ area in the central part of each plot. The seeds were manually threshed from the heads using a metallic stick, and the moisture content was determined immediately after weighing. Sunflower seed yield was reported on a dry weight basis, with a moisture content of 90 g per kg.

### Profitability Analysis

Labour used for various operations, including sowing, thinning, irrigation, fertilizer and pesticide application, harvesting, threshing, and seed cleaning, was recorded. The time (in hours) required for each operation in each treatment plot was recorded using a stopwatch and expressed as person-days $ha^{-1}$, with 8 hours equating to 1 person-day. The variations in seed and labour requirements across different treatments are presented in Table 1. Costs differed among treatments, and profitability was assessed based on total variable cost, gross return, gross margin, and benefit-cost ratio (BCR). Total variable costs encompassed input costs (seeds, fertilizers, and pesticides), labor costs, and irrigation pump rental fees. Gross return was calculated based on grain and stalk prices prevailing in the community.

Table 1. Labour and input that varied among plant densities (spacing).

| Input/labour | Treatments (Spacing) | | |
|---|---|---|---|
| | 75 cm × 45 cm | 60 cm × 45 cm | 45 cm × 30 cm |
| Seed (kg $ha^{-1}$) | 7.5 | 9.5 | 19.0 |
| Labour (person $ha^{-1}$) | | | |
| Sowing | 15 | 19 | 30 |
| Thinning | 4 | 5 | 7 |
| Fertilizer application | 11 | 15 | 25 |
| Harvesting | 14 | 18 | 22 |
| Threshing | 15 | 19 | 23 |
| Drying and cleaning | 4 | 5 | 4 |

**Statistical Analyses**

Data analysis was performed using CROPSTAT 7.2.3.3 version (IRRI, 2007). The least significant difference (LSD) test at $P < 0.05$ was employed to test differences among treatment means. Differences were considered significant at $P \leq 0.05$ unless otherwise indicated.

## Results And Discussion

### Soil Moisture

The interaction between plant density and salt-affected location had no significant on soil moisture from the day of sowing to 60 days after sowing (DAS). Soil moisture remained similar across all treatment plots on these dates (Table 2). Across different sowing densities, soil moisture was consistent at all observation points. However, soil moisture varied among locations from sowing to 60 DAS. Sreefalkathi had higher soil moisture at all points compared to the Bharasimla and Shadpur sites, with moisture levels at the latter two sites being largely similar. Despite the higher soil moisture in Sreefalkathi the site also exhibited higher soil salinity, indicating the site's inherently higher salinity due to its higher sub-soil water salinity levels. The increasing salinity of irrigation water in different sites increased the salinity of the soils and decreased the soil moisture depletion (Pearson, 2003; Salehin et al., 2018).

Table 2. Soil moisture at different dates in various plant densities and locations.

| Factor | Soil moisture (%) | | | | |
|---|---|---|---|---|---|
| | DS | 15 DAS | 30 DAS | 45 DAS | 60 DAS |
| Spacing (T) | | | | | |
| 75 cm × 45 cm | 34.1 | 26.1 | 17.8 | 14.8 | 11.5 |
| 60 cm × 45 cm | 34.7 | 25.5 | 20.4 | 14.8 | 11.3 |
| 45 cm × 30 cm | 34.6 | 26.4 | 20.5 | 15.0 | 10.9 |
| $LSD_{0.05}$ (T) | ns | ns | ns | ns | ns |
| Location (L) | | | | | |
| Shadpur | 27.7 | 22.2 | 17.5 | 13.3 | 8.4 |
| Bharasimla | 37.3 | 23.6 | 16.8 | 13.0 | 10.5 |
| Shreefalkathi | 38.3 | 32.2 | 26.4 | 18.3 | 14.9 |
| $LSD_{0.05}$ (L) | 1.2 | 1.5 | 1.0 | 0.8 | 0.8 |
| $LSD_{0.05}$ (T×L) | ns | ns | ns | ns | ns |

**Soil Salinity**

The interaction between plant density and salt-affected location did not significantly affect the electrical conductivity (ECe) of the soil from sowing to 90 DAS (Table 3). The ECe values of the soil in the treatment plots remained consistent from sowing to 90 DAS, indicating that the treatment effects were not influenced by soil salinity at the different locations. However, ECe varied significantly across locations throughout the study period, with soil salinity following the trend of Sreefalkathi > Bharasimla > Shadpur from sowing to 90 DAS.

Table 3. Soil electrical conductivity at different dates in various plant densities and locations.

| Factor | Electrical conductivity (dS $m^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | DS | 15 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| Spacing (T) | | | | | | | |
| 75 cm × 45 cm | 3.83 | 4.26 | 4.83 | 5.45 | 5.72 | 6.22 | 6.22 |
| 60 cm × 45 cm | 3.79 | 4.26 | 4.84 | 5.43 | 5.72 | 6.26 | 6.12 |
| 45 cm × 30 cm | 3.84 | 4.29 | 4.83 | 5.43 | 5.69 | 6.22 | 6.13 |
| $LSD_{0.05}$ (T) | ns | ns | ns | ns | ns | ns | ns |
| Location (L) | | | | | | | |
| Shadpur | 3.42 | 3.77 | 4.53 | 4.93 | 5.15 | 5.58 | 4.93 |
| Bharasimla | 3.76 | 4.33 | 4.69 | 4.95 | 5.19 | 5.77 | 6.02 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shreefalkathi | 4.28 | 4.70 | 5.28 | 6.43 | 6.79 | 7.34 | 7.71 |
| $LSD_{0.05}$ (L) | 0.09 | 0.04 | 0.05 | 0.05 | 0.04 | 0.06 | 0.06 |
| $LSD_{0.05}$ (T×L) | ns | ns | ns | ns | ns | ns | ns |

**Seed Yield**

The seed yield produced with plant populations of 37037 plants ha$^{-1}$ (60 cm × 45 cm) and 74074 plants ha$^{-1}$ (45 cm × 30) cm was similar and significantly higher than the yield from 29630 plants ha$^{-1}$ (75 cm × 45 cm). Specifically, seed yields from the 60 cm × 45 cm and 45 cm × 30 cm plant spacing were 31.3 % and 22.2 % higher, respectively, than the 75 cm × 45 cm spacing (Figure 1). These findings align with the studies of Li *et al*., (2019) and Mojiri and Arzani (2003). Malik *et al*. (2001) also found higher seed yields with a 60 cm × 30 cm arrangement, while Kaya et al. (2015) reported that a of 60 cm × 35 cm planting pattern was effective for increasing grain yield. Seed yields in Shadpur and Bharasimla were statistically similar but significantly higher than in Sreefalkathi. Yield reductions of 6.5 % and 17.4 % were observed at Bharasimla and Sreefalkathi, respectively, compared to the lowest saline site, Shadpur. This decrease in yield corresponded with an increase in soil salinity, which ranged from 4.93 dS m$^{-1}$ at Shadpur to 6.02 dS m$^{-1}$ at Bharasimla and 7.71 dS m$^{-1}$ at Sreefalkathi (Figure 1). Similar results have been reported by other researchers, who have highlighted the negative impact of salinity on sunflower productivity (Kronzucker and Britto, 2011; Zhang and Shi, 2013). Zeng *et al*. (2015) also found that high salinity (ECe 9.03 to 18.06 dS m$^{-1}$) reduced seed yield by 31 %.

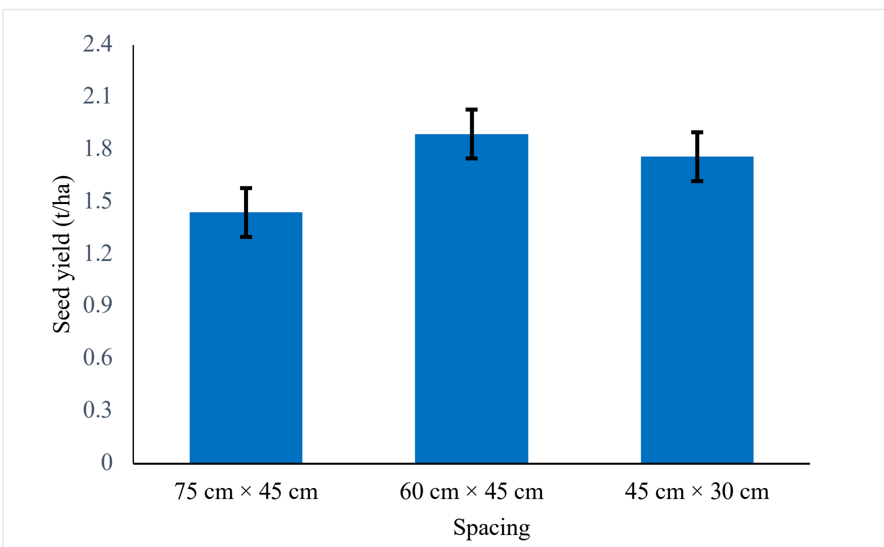


Fig. 1.Seed yield of sunflower as influenced by different pacing. Bars indicate $LSD_{0.05}$.

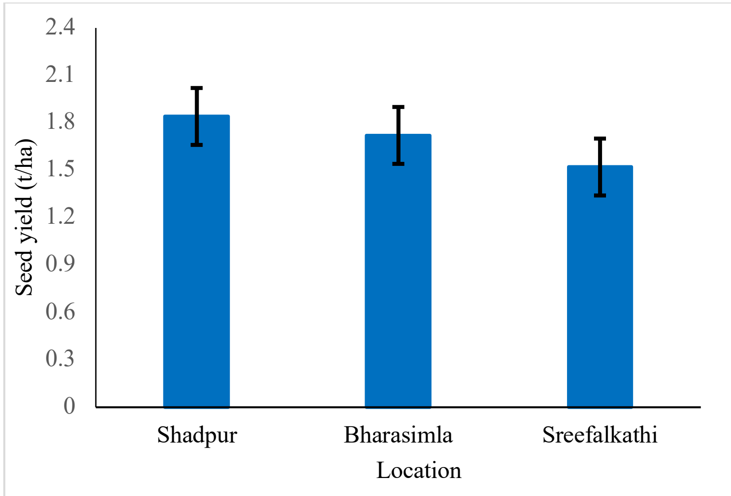


Fig. 2. Seed yield of sunflower as affected by salt affected locations. Bars indicate $LSD_{0.05}$.

**Profitability**

On average, the seed requirements were 7.5, 9.5, and 19 kg ha$^{-1}$ for planting densities of 75 cm × 45 cm (29630 plants ha$^{-1}$), 60 cm × 45 cm (37037 plants ha$^{-1}$), and 45 cm × 30 cm (74074 plant ha$^{-1}$), respectively. Correspondingly, a total of 18 and 38 person-days ha$^{-1}$ were needed for activities such as sowing, thinning, fertilizer application, harvesting, threshing, drying and cleaning in the 60 cm × 45 cm and 45 cm × 30 cm planting densities, respectively. All other costs remained consistent across treatments. The total variable cost was 15.9 and 56.4 % higher in the 60 cm × 45 cm and 45 cm × 30 cm densities, respectively, compared to the 75 cm × 45 cm density. Increasing the planting density from 29630 to 37037 plants ha$^{-1}$resulted in a 24-28 % increase in gross return, while a decrease of 16-22 % was observed in the 45 cm × 30 cm density (74074 plant ha$^{-1}$). The gross margin was highest in the 60 cm × 45 cm density, followed by the 75 cm × 45 cm density, with the lowest in the 45 cm × 30 cm density. Increasing the planting density from 75 cm × 45 cm to 60 cm × 45 cm boosted the gross margin by 35-50 %, but decreased it by 24-49 % in the 45 cm × 30 cm density. The gain in gross return at the 45 cm × 30 cm density was offset by higher total variable cost. The gross margin decreased by 5.5% to 27.1 % in Bharasimla and 28.0% to 53.8 % in Sreefalkathi, compared to the lowest saline site, Shadpur. The benefit cost ratio (BCR) over total variable cost was highest in the 60 cm × 45 cm density, followed by 75 cm × 45 cm, with the lowest in the 45 cm × 30 cm density. The BCR slightly decreased in Bharasimla but significantly in Sreefalkathi (Table 4). The gross margin and BCR were mainly influenced by seed yield, variable seed costs, and labor wages, which varied depending on planting density.

Table 4. Profitability of three plant densities of sunflower at different locations.

| Density | Location | TVC* (BDT $ha^{-1}$) | Gross return** (BDT $ha^{-1}$) | Gross Margin (BDT $ha^{-1}$) | BCR |
|---|---|---|---|---|---|
| 75 cm × 45 cm | Shadpur | 57120 | 99448 | 42328 | 1.74 |
| | Bharasimla | 57120 | 97135 | 40015 | 1.70 |
| | Shreefalkathi | 57120 | 86391 | 29271 | 1.51 |
| 60 cm × 45 cm | Shadpur | 66200 | 127299 | 61098 | 1.92 |
| | Bharasimla | 66200 | 120369 | 54169 | 1.82 |
| | Shreefalkathi | 66200 | 110219 | 44019 | 1.66 |
| 45 cm × 30 cm | Shadpur | 89350 | 121709 | 32358 | 1.36 |
| | Bharasimla | 89350 | 112942 | 23592 | 1.26 |
| | Shreefalkathi | 89350 | 104286 | 14936 | 1.17 |

*TVC = Total variable cost, BDT = Bangladeshi Taka; **Price of seed plus stalk; farm gate seed price $t^{-1}$ BDT 50000, stalk = BDT 22500 $t^{-1}$ for spacing 75 cm × 45 cm and BDT 25000 for spacing 60 cm × 45 cm and 45 cm × 30 cm.

## Conclusions

Our results showed that increasing the planting density from 29,630 to 37,037 and 74,074 plants $ha^{-1}$ significantly increased seed yield in zero-tilled dibbled sunflower, although it also led to higher total variable costs. Seed yield was not significantly affected by salinity levels up to 6.02 dS $m^{-1}$ but declined significantly at 7.71 dS $m^{-1}$. The gain in total return from the highest density of 74074 plants $ha^{-1}$ (45 cm × 30 cm) was nullified by the increased total variable costs. The planting density of 37037 plants $ha^{-1}$ (60 cm × 45 cm) resulted in higher profitability across all salt-affected locations compared to both the lowest density of 29630 plants $ha^{-1}$ (75 cm × 45 cm) and the highest density of 74074 plants $ha^{-1}$ (45 cm × 30 cm), indicating its superior performance. Given the yield advantage and higher profitability, the planting density of 37037 plants $ha^{-1}$ with a spacing of 60 cm × 45 cm is recommended for zero-tilled dibbled sunflower in saline ecosystems. Further validation of this density in different establishment methods within saline environments is also needed. Moreover, studies are required for confirming the potential implications of these findings on long-term sustainability and soil health in saline environments.

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