*Original Research Article*

Evaluation of Selected Salt Tolerant Soybean Genotypes in Southern Saline Soils of Bangladesh

ABSTRACT

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| Globally salinity is one of the most detrimental factors affecting crop growth, development and yield. Understanding crop responses or growth potential and their effectiveness in salinity mitigation is highly important for selecting salinity tolerant crop. Therefore, a research study was undertaken to evaluate the selected soybean genotypes in southern saline soil of Bangladesh. In this study, two selected salt tolerant soybean lines (V1 = Vietkhai and V2 = G 00382), one moderately salt tolerant soybean line (V3 = USDA-15), one salt sensitive soybean variety (V4 = Binasoybean-4) and a standard check (V5 = BARI Soybean-5) were used to know the yield, yield attributes and seed quality parameters of the soybean genotypes in southern saline soils of Bangladesh. The experiments were conducted at two locations of Shatkhira, one is on station (OS), ARS, BARI, Binerpota and another is farmer’s field (FF), Harodda. The experiments in two locations were laid out in RCBD (randomized complete block design) with three replications. During the entire monitoring interval, OS consistently exhibited higher electrical conductivity (EC) over FF. In field condition, the highest seed yield and, germination % of seed, seedling dry weight, seed protein content, oil content of seed, seed vigor index, fatty acid composition of seed and all of the seed quality parameters were found higher from Vietkhai and G 00382 whereas the lowest values were obtained from salt susceptible genotype Binasoybean-4. From the findings of the study, it may be concluded that, soybean genotypes G 00382 and Vietkhai could be recommended as soybean cultivars for southern saline zones of Bangladesh. |

Keywords: Salinity; Seed quality; Soybean; Stress; Yield.

1. INTRODUCTION

Soybean (*Glycine max* L.) belongs to the family Fabaceae is considered to be one of the major oilseeds crops as well as an economically important leguminous crop as it supplies more than 25% of the global protein requirement for food and feed [1]. Soybean is a crop of versatile uses with wide adaptability. Apart from the soybean oil, the whole soybean including pod and seed have various uses like human food, animal feed and in improving soil fertility through N-fixation. In Bangladesh, soybean occupies 0.94 lakh ha of land and its production is 1.73 lakh tons [2]. Among the oilseed crops, soybean occupies only 11.73% area in Bangladesh [3]. Soybean is the most important oil crop because it is cultivated in both Rabi and Kharif season in Bangladesh. Growth, development and yield of soybean are the result of genetic potential interacting with environment. Soybean seed production may be limited by environmental stresses such as soil salinity [4].

In Bangladesh 1.056 m ha land is affected by different degrees of soil salinity [5]. About 32-40% of the coastal area remains fallow in the *rabi* season due to soil salinity [6]. Recently, International Rice Research Institute (IRRI)’s Seed Study, funded by USAID, has identified 12 districts of Bangladesh as salinity affected area through GIS mapping. Estimates from the research indicate that due to salinity Bagerhat, Barguna, Barisal, Bhola, Khulna, Jhalakati, Pirojpur, and Satkhira districts are affected mostly due to salinity. Bangladesh is highly vulnerable to saline water inundation due to sea level rise. World Bank [7] showed 10 cm, 25cm and a 1.0 m rise in sea level by 2020, 2050 and 2100; affecting 2%, 4% and 17.5% of total land mass respectively in Bangladesh.

To improve crop productivity in the salt affected regions, it is necessary to understand the mechanism of plant responses to salt. These responses are complex and different mechanisms are employed by plants when they encounter abiotic stress. However, plant responses depend on the stage of growth, the intensity of stress, rate and duration of exposure to stress, and also on plant species and even cultivar within species [8]. Salt stress is undoubtedly one of the worst conditions for plant growth as it creates both osmotic and ionic stress. Soybean is known to be partially sensitive to salt which may result in up to 40% yield loss depending upon salinity level. The presence of excess salt in the growing medium of soybean negatively affects the quality and quantity of seed, growth, and nodulation process [9]. Synthesis of protein, uptake and transportation of water and nutrient, translocation of assimilates, cytosolic and mitochondrial reactions and several other metabolic pathways are adversely affected by salt stress [10]. Dehydration of cell and toxic ion accumulation occur when the rhizobia-legume symbiosis process is hampered in particular [9].

Soybean was classified as a moderately salt tolerant crop [11] and it has great potentiality to grow in saline soil. So far, seven soybean varieties have been developed at the Bangladesh Agricultural Research Institute (BARI) but no one variety is identified as salt tolerant. However, developments of more salt tolerant varieties are of prime importance for cultivating crop in coastal areas. Keeping the above point in view the current study has been undertaken to search salt tolerant soybean genotypes to bring the uncultivable land of the highly saline affected area under cultivation.

2. material and methods

**2.1 Experimental site, weather and soil**

To evaluate the yield and seed quality parameters of salt tolerant soybean genotypes an experiment was conducted at Binerpota, Satkhira during *Rabi* 2021-2022 in two different locations: i) ARS, Binerpota, Satkhira and ii) Farmer’s field (Location: Harodda, Binerpota, Satkhira during winter (*Rabi)* season of 2021. The agro climatic conditions during the study period have been presented in Figure 1. Geographically, the experimental site is located at 24.36ºN latitude and 88.66º E longitude. The chemical properties of the experimental soil were given in Table 1.

Figure 1: The agro climatic conditions of the experimental site during the study period

**Table 1.** **Chemical properties of the soil of Soybean field at ARS, BARI, Benarpota, Satkhira during the *rabi* season of 2021**

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| --- | --- | --- |
| **Soil characteristics** | **(Initial soil-1 to 20 cm)** | **Critical levels** |
| Value | Interpretation |  |
| Soil pH | 5.57 | Neutral | - |
| Organic matter (%) | 1.27 | Medium | C: N= 10:1 |
| Total N (%) | 0.089 | Very low | 0.12 |
| Available P (ppm) | 14.95 | Medium | 10.0 |
| Exchangeable K (meq/100g soil) | 0.64 | Very high | 0.12 |
| Available S (ppm) | 45.58 | Very high | 10.0 |
| Available Zn (ppm) | 2.42 | Very high | 0.6 |
| Available Boron (ppm) | 0.14 | Low | 0.2 |
| Available Cu (ppm) | 1.78 | Very high | 0.2 |
| Available Fe (ppm) | 123.5 | Very high | 4.0 |
| Available Mg (ppm) | 31.3 | Very high | 0.5 |
| Exchangeable Ca (meq/100g soil) | 32.0 | Very high | 2.0 |
| Mn (ppm) | 17.06 | Very high | 1.0 |
| B (ppm) | 0.29 | Low | 0.2 |

**2.2 Treatment and design**

The ability of soybean genotypes to perform reasonably well in variable salinity stressed environments is an important factor to know the stability of production under salinity stress conditions. In this study, two selected salt tolerant soybean lines (V1 = Vietkhai and V2 = G 00382), one moderately salt tolerant soybean line (V3 = USDA-15), one salt sensitive soybean variety (V4 = Binasoybean-4) and a standard check (V5 = BARI Soybean-5) were used to know the yield attributes and seed quality parameters of the soybean genotypes in southern saline soils of Bangladesh. The experiment was conducted at two locations, one is on station (OS), ARS, BARI, Binerpota, Satkhira and another is farmer’s field (FF), Harodda, Satkhira. The experiment in two locations were laid out in RCBD (randomized complete block design) with three replications.

**2.3 Crop husbandry**

The unit plot size was 3 m × 4 m and seeds were sown with a spacing of 30 cm × 5 cm. Fertilizer N28P35K60S20ZZn1B1.7 kg ha-1 (urea = 60 kg, TSP = 175 kg, MoP = 120 kg, gypsum = 115 kg, boron = 10 kg ha-1) were used to cultivate the crop. All of the fertilizers were broadcasted before final land preparation. The crops were sown on 11 January 2021 in ARS Binerpota, Satkhira and 12 January 2021 in farmer’s field (Harodda, Binerpota, satkhira). Weeding, thinning and other intercultural operations were done to establish the crops in both the locations. Dithane M-45 @ 0.2% was applied against stem rot when necessary. Bavistin @ 1g L-1 was applied 3 times at 10 days interval against cercospora leaf spot. The genotypes were harvested when plant attained full maturity, which varied genotype to genotype. The genotype USDA-15 in both the locations were harvested at 11 April 2021 at 90 days after sowing and the other genotypes were harvested at maturity at 25 April 2021 in ARS Binerpota, Satkhira and 26 April 2021 in Farmer’s field (Harodda, Binerpota, satkhira) at 108 days after sowing.

**2.4 Data collection**

Data on yield and yield components, like plant height in cm, no. of primary branches plant-1, no. of pods plant-1, no. of seeds pod-1, 100- seed weight (g), seed yield (kg ha-1) were recorded. To measure seed quality seed germination rate (%), seedling dry matter (mg), seed vigor index (svi), protein content in seed (%), oil content in seed (%) and fatty acid profile were taken.

**2.5 Soil sample collection for salinity measurement**

Soil samples were collected for recording the data of salinity measurements starting from initial to harvest at 15 days interval. Soil salinity was measured at Soil Science Laboratory, ARS, Binerpota, Satkhira.

**2.6Location of seed quality parameters study**

Laboratory of Seed Technology Division; Central Laboratory; Molecular Breeding Laboratory, Plant Breeding Division; BARI, Joydebpur, Gazipur. Fatty acid profile was determined with a GC (Gas Chromotography) machine in central laboratory of BARI, Joydebpur, Gazipur.

**2.7 Statistical Analysis**

Statistical analysis of the data was carried out using the computer based statistical package STATISTIX 10 and STAR 2.0.1 software. Means were compared by employing Least Significant Difference (LSD) Test at 5 % significance level of probability.

3. results and discussion

**3.1 Salinity status of the locations**

The dataset tracks changes in soil electrical conductivity (EC) in two distinct zones which were On-Station (OS) and Farmers’ Field (FF) across the 2021 soybean season. Measurements recorded before planting on 11 January showed nearly identical EC values (OS at 4.63 dS/m, FF at 3.95 dS/m). Following this baseline, both sites experienced gradual EC increases, with pronounced rises beginning in early March. Peak EC levels on 27 April recorded 13.35 dS/m in OS and 10.55 dS/m in FF. During the entire monitoring interval, OS consistently exhibited higher EC (Figure 1).

OS= On station (OS) ARS, BARI, Binerpota, Satkhira and FF=Farmer’s field (FF), Harodda, Satkhira; V1 = Vietkhai, V2 = G 00382, V3 = USDA-15, V4 = Binasoybean-4, V5 = BARI, Soybean-5; BS= Before Sowing; AI= After Irrigation

 **Figure 2:** **Salinity status of the locations over time**

**3.2 Effect over locations on yield attributes and seed quality parameters of soybean**

Location exerted significant effect on plant height, branches plant-1, pods plant-1, seeds pod-1 and seed yield (Table 2). It is observed that plant height was higher (40.49 cm) in FF compared to OS (37.03 cm). Similarly, maximum branches plant-1 (4.23) and pods plant-1 (40.2) were also found from FF whereas minimum branches plant-1 (1.96) and pods plant-1 (19.6) were found from OS. But higher number of seeds pod-1 (2.62) was found in OS than FF (2.48). There was no significant variation noticed in case of hundred seed weight due to locations moreover numerically the higher value of hundred seed weight (9.60 g) was found from OS than FF (9.25 g). On the contrary, seed yields of the varieties varied over locations, where the higher seed yield (1351 kg ha-1) was obtained from farmer’s field of Harodda, and the lower seed yield (1008.4 kg ha-1) was from on station (Table 2).

The study found that seed germination percentage and seed protein content were not significantly affected by location. Numerically, the higher seed germination rate (75.28%) was found in the farmer's field of Harodda, while the lower rate (74.78%) was found in the seed of OS. The oil content of the harvested seed was also non-significant by location, with higher oil content (18.38%) found in OS seeds and lower oil content (18.31%) in farmer's field seeds. Seedling dry weight and seed vigor index were also non-significant by location, with numerically higher amounts in OS seeds and lower amounts in farmer's field seeds.

**3.3 Effects of genotypes on yield attributes and seed quality parameters of soybean**

Plant height, branches plant-1, pods plant-1, seeds pod-1, 100-seed weight and seed yield were significantly influenced by soybean genotypes (Table 2). Significantly the tallest plant (43.45 cm) was found from G 00382 soybean genotype and it was statistically similar with BARI Soybean-5 genotype (42.28 cm). Significantly the shortest plant (32.40 cm) was found from Binasoybean-4 and it was statistically similar to USDA-15 (35.82 cm) soybean genotype. The highest number of branches plant-1 (3.52) was produced by Vietkhai and it was followed by G 00382 (3.30) and BARI Soybean-5 (3.21) genotypes. Significantly the lowest number of branches plant-1 (2.71) was found from Binasoybean-4 and it was statistically similar with USDA-15 (2.72) genotype. The maximum number of pods plant-1 (35.16) was found from G 00382 and it was statistically identical to Vietkhai (33.60). Similarly, G 00382 variety produced higher seeds pod-1 (2.72), 100-seed weight (11.20 g) and seed yield (1679.0 kg ha-1) over other varieties. But the lowest number of pods plant-1 (24.77), seeds pod-1 (2.46) and 100-seed weight (8.08 g) were found from USDA-15 which was statistically similar with Binasoybean-4 (26.02) (Table 2). Significantly the lowest seed yield (907.3 kg ha-1) was found from Binasoybean-4 genotype and it was statistically similar with USDA-15 genotype.

Seed germination rate was significantly influenced by the effect of soybean genotypes (Table 2). The highest seed germination rate (87.73%) was found in G 00382 genotype and it was followed by Vietkhai (81.83%) and BARI Soybean-5 (72.26%). Significantly the lowest seed germination rate (65.83%) was found from Binasoybean-4 and it was statistically similar with USDA-15 (67.50%) (Table 2). Seed protein content was significantly influenced by genotype. Significantly, the highest seed protein content (32.97%) was found in USDA-15 which was statistically identical to Vietkhai (32.49%), BARI Soybean-5 (31.84%) and Binasoybean-4 (31.29%) genotypes. Significantly the lowest seed protein content (29.65%) was found in G 00382.

**3.4 Combined effects of location and soybean genotypes on yield attributes and seed quality parameters**

Combined effect of location and soybean genotypes had no significant role on plant height of the crop (Table 2). Numerically, the tallest plant (44.63 cm) was found from BARI Soybean-5 at Harodda but the shortest plant (30.76 cm) was documented in Binasoybean-4 at Satkhira. Soybean genotypes cultivated in different location and significantly showed variation in terms of number of branches plant-1. Significantly the maximum number of branches plant-1 (4.62) was found from Vietkhai at Harodda whereas lowest number of branches plant-1 (1.33) was found from USDA-15 at OS (Satkhira). Significantly, the highest number of pods plant-1 (45.22) was found from FF and G 00382 treatment combination and the lowest numbers of pods plant-1 (9.40) was found from OS and USDA-15 treatment combination (Table 2). Seeds pod-1 and 100-seed weight were not significantly affected by the combined effect of location and soybean genotypes. Seed yield was significantly influenced by the combined effect of location and soybean genotypes (Table 2). Significantly the highest seed yield (1899.3 kg ha-1) was found from from FF and G 00382 treatment combination and it was followed by OS and G 00382 (1458.6 kg ha-1), FF and BARI Soybean-5 (1315.3 kg ha-1), FF and USDA-15 (1263.6 kg ha-1), treatment combination. But minimum seed yield (686.3 kg ha-1) was found from OS and Binasoybean-4 treatment combination and it was followed by OS and USDA-15 (786.3 kg ha-1), OS and BARI Soybean-5 (928.3 g), FF and Binasoybean-4 (1128.3 kg ha-1) and FF and Vietkhai (1148.6 kg ha-1) (Table 2).

Seed germination rate was not significantly influenced by the combined effect of location and soybean genotypes (Table 2). Moreover, the highest seed germination rate (87.93%) was found from OS and G 00382 treatment combination. The lowest seed germination rate (65.13%) was found from OS and Binasoybean-4 treatment combination. But the seed protein percent was significantly affected at 5% level of probability by the combined effect of location and soybean genotypes. Significantly the highest seed protein content (34.63%) was found from FF and Vietkhai treatment combination which was statistically identical to FF and USDA-15 (34.54%) treatment combination. Significantly the lowest seed protein content (29.29%) was found from FF and G 00382 treatment combination (Table 2). Contrarily, seed oil content was not significantly affected by the combined effect of location and soybean genotype. Seedling dry weight and seed vigor index also followed similar pattern.

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| Table 2. Effect of Location, Variety and Combined effect of Location and Variety on yield attributes, yield and seed quality parameters of soybean genotypes during r*abi* (winter) season  |
| Location | **Plant height****(cm)** | **Branches plant-1****(no.)** | **Pods plant-1****(no.)** | **Seeds pod-1****(no.)** | **100-seed weight (g)** | **Seed Yield****(kg ha-1)** | **Germination (%)** | **Seed protein content (%)** | **Seed oil content (%)** | **Seedling dry weight (mg)** | **Seed vigor index** |
| OS (Satkhira) | 37.03b\* | 1.96 b | 19.6 b | 2.62 a | 9.60 | 1008.4b | 74.78 | 31.40 | 18.38 | 87.71 | 6468.5 |
| FF (Harodda) | 40.49 a | 4.23 a | 40.2 a | 2.48 b | 9.25 | 1351.0a | 75.28 | 31.88 | 18.31 | 87.61 | 6528.5 |
| CV (%) | 6.78 | 4.44 | 9.39 | 2.99 | 9.92 | 12.36 | 4.67 | 5.058 | 5.064 | 4.42 | 6.53 |
| Level of sig. | \*\* | \*\*\* | \*\*\* | \*\*\* | ns | \*\*\* | ns | ns | Ns | ns | ns |
| Variety |
| V1 | 39.45 b | 3.52 a | 33.60 a | 2.52 bc | 10.25 ab | 1165.6 b | 81.83 b | 32.49 a | 18.6 | 85.61bc | 6907.4b |
| V2 | 43.45 a | 3.30 b | 35.16 a | 2.72 a | 11.20 a | 1679.0 a | 87.73a | 29.65 b | 18.6 | 92.93a | 8079.2a |
| V3 | 35.82 c | 2.72 c | 24.77 c | 2.46 c | 8.20 c | 1025.0 bc | 67.50d | 32.97 a | 17.9 | 92.30a | 6119.5c |
| V4 | 32.80 c | 2.71 c | 26.02 c | 2.49 bc | 8.08 c | 907.3 c | 65.83d | 31.29ab | 18.38 | 81.08c | 5244.4d |
| V5 | 42.28 ab | 3.21 b | 30.03 b | 2.56 b | 9.40 b | 1121.8 b | 72.26c | 31.84 a | 18.14 | 86.38 b | 6142.2c |
| CV (%) | 6.78 | 4.44 | 9.39 | 2.99 | 9.92 | 12.36 | 4.67 | 5.058 | 5.061 | 4.42 | 6.53 |
| Level of sig. | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \* | Ns | \*\*\* | \*\*\* |
| Location x Variety |
| OS | V1 | 37.84 cd | 2.43 c | 27.96 c | 2.60 | 10.6 | 1182.6 c | 81.06 | 30.36 cd | 18.93 | 85.56 | 6877.6 |
| V2 | 42.77 ab | 2.43 c | 25.10 cd | 2.83 | 11.3 | 1458.6 b | 87.93 | 30.01 cd | 18.12 | 90.10 | 7817.9 |
| V3 | 33.87 de | 1.33 d | 9.40 f | 2.46 | 8.00 | 786.3 e | 65.93 | 31.41b-d | 18.08 | 93.43 | 6041.0 |
| V4 | 30.76 e | 1.36 d | 14.46 e | 2.56 | 8.33 | 686.3 e | 65.13 | 32.07 a-c | 18.74 | 80.90 | 5154.3 |
| V5 | 39.92 bc | 2.23 c | 21.10 d | 2.66 | 9.66 | 928.3 de | 73.86 | 33.23 ab | 18.02 | 88.56 | 6451.8 |
| FF | V1 | 41.06 a-c | 4.62 a | 39.24 b | 2.44 | 9.83 | 1148.6 cd | 82.60 | 34.63 a | 18.32 | 85.66 | 6937.2 |
| V2 | 44.13 ab | 4.17 b | 45.22 a | 2.62 | 11.0 | 1899.3 a | 87.53 | 29.29 d | 19.18 | 95.76 | 8340.5 |
| V3 | 37.77 cd | 4.11 b | 40.15b | 2.46 | 8.40 | 1263.6 bc | 69.06 | 34.54 a | 17.79 | 91.16 | 6198.0 |
| V4 | 34.84 de | 4.06 b | 37.57 b | 2.42 | 7.83 | 1128.3 cd | 66.53 | 30.52b-d | 18.02 | 81.26 | 5334.4 |
| V5 | 44.63 a | 4.20 b | 38.97 b | 2.46 | 9.13 | 1315.3 bc | 70.66 | 30.46 cd | 18.26 | 84.20 | 5832.5 |
| CV (%) | 6.78 | 4.44 | 9.39 | 2.99 | 9.92 | 12.36 | 4.67 | 5.058 | 5.064 | 4.42 | 6.53 |
| Level of sig. | NS | \*\*\* | \*\*\* | NS | NS | \* | NS | \*\* | NS | NS | NS |
| \*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); \*= Significant at 5% level of probability, \*\* =Significant at 1% level of probability, \*\*\*= Significant at 1% level of probability; NS = Non-significant; OS = On station, FF = Farmer’s field, V1 = Vietkhai, V2 = G 00382, V3 = USDA-15, V4 = Binasoybean-4, V5 = BARI, Soybean-5  |

**3.5 Effect of locations on fatty acid profile of soybean seed**

Location exerted significant effect on fatty acid profile (Table 3). The higher amount of myristic acid (0.68%) was observed in the seed of FF and the lower amount of myristic acid (0.09%) was obtained in the seed of OS location. Similarly, the palmitic acid (14.55%), palmitolic acid (2.00%) and stearic acid (3.95%) was also more in the seed obtained from FF and less (13.57%) in the seed obtained from OS location. But the higher amount of oleic acid (26.17%) and lenoleic acid (50.94%) were observed in the seed of OS and the lower amount of oleic acid (24.52%) was obtained in the seed of FF location (Table 3). The higher amount of linolenic acid (7.94 %) was observed in the seed of FF and the lower amount of linolenic acid (6.44%) was obtained in the seed of OS location.

**3.6 Effect of soybean variety on fatty acid profile of soybean seed**

Myristic acid was significant at 0.1% level of probability by the effect of soybean genotypes. The highest content of myristic acid (1.57%) was found from Vietkhai and it was followed by USDA-15(0.26%), G 00382 (0.19%), and Binasoybean-4 (0.06%). The lowest myristic acid content was found in BARI, Soybean-5 (0.14%).On the other hand**,** the highest palmitic acid content (16.57%) was observed in Binasoybean-4 and the next highest palmitic acid 15.08% was recorded in G 00382 soybean genotype whilst the lowest palmitic acid content (12.44%) was obtained in the seed of USDA-15 and it was statistically similar with Vietkhai (12.72) and BARI Soybean-5 (13.48) (Table 3).Similarly, the highest palmitolic acid content (2.46%) was found in Binasoybean-4 genotype and it was followed by G 00382 (1.83%) and Vietkhai (0.59%). Significantly the lowest palmitolic acid content (0.115) was found in BARI Soybean-5 genotype and it was statistically similar with USDA-15 (0.12%) (Table 3). The highest stearic acid content (4.14%) was found in Vietkhai genotype and it was statistically similar with BARI, Soybean-5 (3.95%). Significantly the lowest content of stearic acid (2.56%) was found from the seed of USDA-15 genotype and it was statistically identical to G 00382 (2.71%) (Table 3). The highest oleic acid content (36.47%) was observed in the seed of USDA-15 soybean genotype. Significantly the lowest oleic acid (W-9) content (20.45%) was found from the seed of G 00382 genotype and it was statistically similar with Vietkhai (21.15%) and Binasoybean-4 (22.18%) (Table 3). The highest lenoleic acid content (55.00%) was found from the seed of Vietkhai genotype and it was followed by BARI Soybean-5 (49.69%) and G 00382 (49.16%). Significantly the lowest lenoleic acid (W-6) content (43.57%) was found from the seed of USDA-15 and it was statistically similar with Binasoybean-4 (45.83%). Linoleic acid (W-3) content (10.57%) was higher in G 00382 and it was followed by Binasoybean-4 (9.14%) and BARI Soybean-5 (6.08). Significantly the lowest content of linoleic acid (W-3) (4.56%) was obtained in the seed of USDA-15 and it was statistically similar with Vietkhai (4.85) (Table 3).

**3.7 Combined effect of location and variety on fatty acid profile of soybean seed**

Significantly the highest content of myristic acid (3.03%) was found in Vietkhai when cultivated at FF (Harodda). But Palmitic acid content (19.31%) was more in Binasoybean-4 at FF (Harodda) whereas the lowest amount of palmitic acid (11.03%) was found from OS (Satkhira) and USDA-15 treatment combination. Significantly the highest amount palmitolic acid (4.89%) was found from FF (Harodda) and Binasoybean-4 treatment combination whereas lowest palmitolic acid was found from OS (Satkhira) and Binasoybean-4 (0.020%) (Table 3). Significantly the highest amount stearic acid (6.01%) was found from FF (Harodda) and Vietkhai treatment combination. Significantly the lowest amount of stearic acid (2.26%) was found from OS (Satkhira) and Vietkhai treatment combination (Table 4). The highest oleic acid (38.51%) was found from OS (Satkhira) and USDA-15 treatment combination. On the other hand, the lowest oleic acid (17.97%) was found from FF (Harodda) and Binasoybean-4 and it was statistically identical (Table 3). Vietkhai variety when cultivated in FF (Harodda) produced more Linoleic acid (55.17%). In contrast Binasoybean-4 had the minimum content (41.03%) was found from FF (Harodda). In case of linolenic acid variety G 00382 performed well with 13.70 % content at FF (Harodda) but the lowest amount of linolenic acid (2.45%) was found from FF and Vietkhai treatment combination.

**Table 3: Fatty acid profile of selected soybean genotypes over location during r*abi* (winter) season**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Myristic acid (%) | Palmitic acid (%) | Palmitolic acid (%) | Stearic acid (%) | Oleic acid(W-9) (%) | Linoleic acid(W-6) (%) | Linolenic acid(W-3) (%) |
| OS | 0.09 b\* | 13.57 b | 0.106 b | 2.895 b | 26.166 a | 50.94 a | 6.440 b |
| FF | 0.68 a | 14.55 a | 2.00 a | 3.945 a | 24.522 b | 46.36 b | 7.938 a |
| CV (%) | 5.78 | 7.728 | 12.915 | 4.962 | 5.998 | 4.909 | 7.374 |
| Level of sig. | \*\*\* | \* | \*\*\* | \*\*\* | \*\* | \*\*\* | \*\*\* |
| Variety |
| V1 | 1.565 a | 12.72 c | 0.586 c | 4.135 a | 21.15 c | 54.995 a | 4.845d |
| V2 | 0.185 c | 15.08 b | 1.825 b | 2.708 c | 20.45 c | 49.16 b | 10.57 a |
| V3 | 0.255 b | 12.44 c | 0.118 d | 2.563 c | 36.47 a | 43.57 c | 4.56 d |
| V4 | 0.0583 d | 16.57 a | 2.455 a | 3.743 b | 22.18 c | 45.83 c | 9.146 b |
| V5 | 0.148 e | 13.48 c | 0.115 d | 3.951 a | 26.45 b | 49.69 b | 6.808 c |
| CV (%) | 5.779 | 7.728 | 12.915 | 4.962 | 5.9982 | 4.909 | 7.374 |
| Level of sig. | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* |
| Location x Variety |
| OS  | V1 | 0.100 d | 13.22 cd | 0.126 e | 2.256 f | 22.48 e | 54.82 a | 7.243 c |
| V2 | 0.183 c | 16.99 b | 0.083 e | 2.400 f | 18.99 g | 54.06 ab | 7.456 c |
| V3 | 0.260 b | 11.03 e | 0.186 e | 2.303 f | 38.51 a | 43.40 e | 4.29 f |
| V4 | 0.053 e | 13.83 cd | 0.020 e | 3.340 d | 26.39 cd | 50.64 bc | 5.716 de |
| V5 | 0.15 f | 12.77 cde | 0.526 d | 4.176 b | 24.44 de | 51.79 ab | 7.49 c |
| FF | V1 | 3.030 a | 12.21 de | 1.30 c | 6.013 a | 19.82 fg | 55.17 a | 2.446 g |
| V2 | 0.186 c | 13.18 cd | 3.73 b | 3.016 e | 21.91 ef | 44.27 de | 13.70 a |
| V3 | 0.250 b | 13.85 cd | 0.050 e | 2.823 e | 34.43 b | 43.74 de | 4.843 ef |
| V4 | 0.063 de | 19.31 a | 4.89 a | 4.146 b | 17.97 g | 41.03 e | 12.57 b |
| V5 | 0.143 f | 14.19 c | 0.040 e | 3.726 c | 28.46 c | 47.59 cd | 6.123 d |
| CV (%) | 5.779 | 7.728 | 12.915 | 4.962 | 5.998 | 4.909 | 7.374 |
| Level of sig. | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\*\* | \*\* | \*\*\* |

\*In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); \*= Significant at 5% level of probability \*\* =Significant at 1% level of probability, \*\*\*= Significant at 0.5% level of probability OS = On station, FF = Farmer’s field, V1 = Vietkhai, V2 = G 00382, V3 = USDA-15, V4 = Binasoybean-4, V5 = BARI Soybean-5

**4. DISCUSSION**

In the study, crop received different levels of salinity stress during the growth period which was due to soil salinity by nature and was continued up to maturity. Therefore, the plants experienced salinity stress throughout the growing period and both vegetative and reproductive stages were affected severely due to soil salinity stress.

In our experiment it was found that in terms of plant growth and yield parameters soybean genotypes performed well in FF (Harodda) as compared to OS (satkhira). This might be due to the salinity differences in the locations. Over the course of the monitoring period, OS continuously showed greater EC suggesting a greater accumulation of salts; this is likely attributable to differences in soil texture, drainage, and irrigation strategies. By contrast, FF exhibited persistently lower EC, indicating more effective natural leaching and reduced salt concentration. These findings underscore how site-specific variables govern salinity pattern and highlight the critical roles of site selection and tailored field management in minimizing salt stress in soybean cultivation.

Moreover, the salt tolerant varieties showed higher values of growth and yield parameters than others. Salt-tolerant plant varieties cope with saline environments by employing mechanisms that regulate ion balance, osmotic adjustment, and reactive oxygen species (ROS) detoxification, while susceptible varieties often suffer from the toxic effects of high salt concentrations [12].

Varieties performed differently under On-Station (OS, Satkhira) and Farmers’ Field (FF, Harodda) conditions, with FF generally supporting better plant growth and productivity. These results indicate that varietal response to environmental conditions varies significantly. Similar findings were reported by Tsui-Hung *et al.* [13] and Amirjani MR [14]. Salinity inhibits plant growth by lowering the water potential of the leaf, causing physiological and morphological changes, generating reactive oxygen species, ion toxicity, increasing osmotic stress, and changing biochemical processes [15]. One of the earliest impacts of salt stress is a slowdown in the growth of plants. Salt present in soil and water inhibits the growth of plants for two reasons. It first slows the plant’s ability to absorb water, which causes slower development. This is salinity’s osmotic or water-deficit impact [15]. Our results were similar with the findings of Chang *et al.* [16] where they observed that the agronomic traits of soybean were severely affected by high salinity, including reduction in plant height, number of internodes, number of branches, number of pods, weight per plant and weight of 100 seeds [16].

Our results were also supported by the findings of Mahfuza *et al.* [17] where they observed that plant height, number of filled pods plant-1 and seed yield was significantly influenced by soil salinity. The higher the salinity, the lower the yield contributing parameters were observed. The seed yield reduction percentage was higher in Shohag which was 20, 43 and 62% in 4, 8 and 12 dSm-1 salinity stresses, respectively compared to control [17]. On the other hand, BARI Soybean-6 showed relatively lower seed yield reduction i.e., 6, 28 and 38% in 4, 8 and 12 dS m-1 salinity stresses, respectively compared to control. BARI Soybean-5 and Binasoybean-4 gave moderate seed yield in all salinity levels compared to control [17].

The results indicated that G 00382 performed the best followed by Vietkhai in terms of seed germination% of the soybean genotypes. The genotype Binasoybean-4 performed the worst and identical with USDA-15. This is might be due to the inherent capacity of the soybean genotypes which was controlled by salt tolerant related gene. The cultivar G 00382 and Vietkhai were less affected than USDA-15 and Binasoybean-4 genotypes. Our results were similar with the findings of Essa [18] where he observed that germination percentages were significantly reduced with increasing salinity levels.

It is found that protein content and oil content of soybean seed was reversely influenced. In most of the cases of soybean genotypes, it is observed that where the protein content increased, there was found the decreased content of seed oil content. The quality of soybean seeds (the primary agricultural product) is also affected by salt stress. In general, salt stress reduces the protein contents in soybean seeds [19]. However, the effect of salt on oil content of soybean seeds is still inconclusive since experimental results varied in different field sites using different cultivars treated with different salinity levels (16,19]. The seedling dry weight is one of the indicators of seed quality by which the strength of a seed lot could be understood to produce good seedling. From the study it was found that in most of the cases seedling dry weight was influenced by seed size. The variety G 00382 had the highest seed size (100-seed weight) and produced the highest seedling dry weight, where the variety Binasoybean-4 had lowest seed size (100-seed weight) and produced the lowest seedling dry weight. The reduction in dry weight also may be due to the toxic effect of Na+ on the rate of photosynthesis at salinity stress concentrations. Furthermore, excessive salt levels can induce a decrease in the transport rate of important ions like NO3-, which reduces N-containing molecules and, as a result, inhibits plant development and biomass accumulation [20-21]. The variety G 00382 gave the highest seedling dry weight and it was followed by Vietkhai, USDA-15 and BARI Soybean-5. The variety Binasoybean-4 gave the lowest seedling dry weight. Seed vigor index is the product of germination percent and seedling dry weight. So, the variety performed well in germination percent and seedling dry weight, give the higher value in seed vigor index. Seed vigor index is one of the indicators of seed, by which it can be understood of a seed lot, how much potential of a seed lot to produce good seedling and uniform stand establishment in adverse situation. So, the higher the seed vigor index, the higher the planting value of seed with good quality. In our experiment, it was found that, the soybean variety G 00382 performed the best in seed vigor index and the next highest value was found from Vietkhai. The soybean variety Binasoybean-4 gave the lowest value in seed vigor index. Similar trend was found from the combined effect of location and variety in seed vigor index of soybean seed. Our results were supported by Ramaswamy and Seeta [22] where they found in sunflower that seedlings of fresh weight and dry weight were significantly difference in salinity stress and the toxic effect of salt stress was more in case of salt sensitive Reyflo and Clara genotypes and least in case of salt tolerant Olinda and Cleo genotypes of sunflower.

Fatty acid composition was analyzed to know the seed quality parameter of soybean variety used in the experiment conducted in southern saline soils of Bangladesh. Soybean oil is composed of different fatty acid. It is found that, most of the fatty acid, except oleic acid and linolenic acid, their content was significantly decreased due to location. It is noticed that the soil salinity was higher in OS as compared to FF. Higher level of soil salinity reduces the physiological activity of the crop, inhibits the metabolic activity, reduces the detoxification capacity of ROS and gave the lower accumulation of reserved food material to the crop and ultimately gave the low seed yield in soybean. Higher level of salinity, reduces the life cycle of soybean crop. The more stressed plant gets comparatively shorter time for reserve food material within the economic part of the crop. These results were similar with the findings of Ghassemi-Golezani *et al.* [23] where they observed that oil and protein yields per plant of soybean decreased as salinity increased. These reductions were mainly attributed to the short duration of protein and oil accumulation and grain yield per plant under saline conditions. Research result indicated that oleic acid content of soybean seed increased in salinity stress, but percentages of linoleic acid and linolenic acid of soybean oil decreased with increasing salinity. Similar findings were also documented by Ghassemi-Golezani *et al.* [24].

It is found that fatty acid composition is mainly influenced by soil salinity although there has varietal difference. Same variety performed well in lower level of salinity in FF (Harodda) those that of OS (Satkhira). Among the soybean variety, it was previously found that Vietkhai and G 00382 had the higher capacity to maintain their physiological activity in salinity stress compared to other variety. The variety Vietkhai and G 00382 performed with lower Na+/K+ ratio, higher chlorophyll content, higher capacity to detoxification of ROS, higher photosynthetic rate and higher biochemical mechanisms to continue their lifecycle in salinity stress condition, where Binasoybean-4 performed the worst and USDA-15 as moderate performer. The genotypic variation of soybean variety might be due to their diverse germplasm and their origin. Our findings were supported by Ahmed *et al.* [25] where they found the significant differences (P < 0.001) among four soybean germplasm origins for all fatty acid contents investigated. These results are in accordance with the findings of Hadi *et al.* [26] where they observed in safflower that there were significant effects of genotype, salinity and their interactions on most of the characteristics examined. Salt tolerant genotypes were less affected by salinity than salt-sensitive ones for oil quantity and quality. Our findings were also supported by Eman *et al.* [27] where they found that, soybean cultivars showed a wide range of variation in their salinity sensitivity.

**5. CONCLUSION**

Regarding seed yield, seed quality parameters, seed protein, seed oil and fatty acid composition, the genotype G 00382 performed the best and Vietkhai performed as next, where USDA-15 appears as moderate and Binasoybean-4 appears as the worst performer at Satkhira region in southern saline soils of Bangladesh. Further investigation needs to be done with more and diverse germplasm to dissect in-depth salt tolerance mechanisms. More multilocation trials should be conducted to ensure the adaptation of the salt tolerant soybean genotypes G 00382 and Vietkhai in southern saline soils of Bangladesh.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

1. Liu, S., Zhang, M., Feng, F., & Tian, Z. (2020) Toward a “green revolution” for soybean. *Molecular Plant*, 3, 688-697.
2. DAE (Department of Agricultural Extension). Agricultural Information Services-2024, Government of the Peoples Republic of Bangladesh. Dhaka.
3. BBS (Bangladesh Bureau of Statistics). (2024). Statistical Yearbook Bangladesh 2024 4th Edition. Statistics & Informatics Division (Sid), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh [www.bbs.gov.bd.](http://www.bbs.gov.bd/)
4. Ghassemi-Golezani, K. & Farhangi-Abriz, S. (2018).Changes in oil accumulation and fatty acid composition of soybean seeds under salt stress in response to salicylic acid and jasmonic acid. RCSI Journal, 65(2),229-236. doi.org/10.1134/ S1021443718020115.
5. SRDI (Soil Resources Development Institute) 2010: Saline Soils of Bangladesh. SRMAF Project report. SRDI, Farmgate, Dhaka-1215. p. 1.
6. BARC (Bangladesh Agricultural Research Council). (2020). Annual Report: BARC, New Airport Road, Farmgate, Dhaka-1215, Bangladesh.
7. WB (World Bank). (2000). World Bank Climate Change Knowledge Portal. <http://climateknowledgeportal.worldbank.org>
8. Brar, G. S., Kar, S., & Singh, N. T. (1990). Photosynthetic response of wheat to soil water deficits in the tropics. *Journal of Agronomy and Crop Science*, 165(5), 343-348.
9. Khan, M. A., Asaf, S., Khan, A. L., Ullah, I., Ali. S., & Kang, S.M. 2019: Alleviation of salt stress response in soybean plants with the endophytic bacterial isolate *Curtobacterium sp.* SAK1. *Annals of Microbiology*, 69, 797-808.
10. Alharby, H. F., Hasanuzzaman, M., Al-Zahrani, H. S., & Hakeem, K. R. (2021). Exogenous selenium mitigates salt stress in soybean by improving growth, physiology, glutathione homeostasis and antioxidant defense. *Phyton-International Journal of Experimental Botany*, 90**,** 373-388.
11. Ashraf, M. (1994). Breeding for salinity tolerance in plants. *Critical Review of Plant Sciences*, **1**3, 17-42.
12. Gupta, B., & Huang, B. (2014). Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. *International Journal of Genomics*. 2014, 701596. doi:10.1155/2014/701596
13. Phang, T. H., Shao, G, & Lam, H.M., & Lam, M. (2008). Salt tolerance in soybean. *Journal of Integrative Plant Biology*, 50(10), 1196-1212.
14. Amirjani, M. R. (2010). Effect of salinity stress on growth, mineral composition, proline content, antioxidant enzymes of soybean. *American Journal of Plant Physiology*, 5(6), 350-360.
15. Pandit, K., Kaur, S., Kumar, M., Bhardwaj, R. & Kaur, S. (2024). Salinity stress: Impact on plant growth. *In Advances in Food Security and Sustainability,* 9, 145-160. https://doi.org/10.1016/bs.af2s.2024.07.002
16. Chang, R. Z., Chen, Y.W., Shao, G. H., & Wan, C. W. (1994). Effect of salt stress on agronomic characters and chemical quality of seeds in soybean. *Soybean Science*, 13**,** 101-105.
17. Mahfuza, S. N., Ahsan, A. F.M. S., Ahmed, I. M., Ahmed, F., Rahman Talukder, A. H. M. M., & Islam, M. N. (2022). Morpho-physiological responses of soybean varieties to salinity stress. *Bangladesh Agronomy Journal*, 25(1),15-22.
18. Essa, T. A. (2002). Effect of salinity stress on growth and nutrient composition of three soybean (*Glycine max* L. Merrill) cultivars. *Journal of Agronomy and Crop Science*, 188**,** 86-93. doi: 10.1046/j.1439-037X.2002. 00537.x
19. Wan, C., Shao, G., Chen, Y., & Yan, S, (2002). Relationship between salt tolerance and chemical quality of soybean under salt stress. Chinese Journal of Oil Crop Science 24 67–72.
20. Hamid, M., Ashraf, M.Y. & Arashad, M. (2008). Influence of salicylic acid seed priming on growth and some biochemical attributes in wheat grown under saline conditions. *Pakistan Journal of Botany*, 40(1), 361-367.
21. Sadia, A., Hossain, F., Halim, M. A. & Akhtar, N. (2023). Comparative study of salt tolerance between two soybean varieties (*Glycine max*. L) at germination stage. *Jahangirnagar University Journal of Biological Science*, 12(1 & 2), 35-44.
22. Ramaswamy, A., & Seeta, S. R. R. 2018: Effect of salinity stress on seedling growth of sunflower (*Helianthus annuus* L.) genotypes. *International Journal of Biological Research,* 3(1)70-75.
23. Ghassemi-Golezani, K., Taifeh-Noori, M., Oustan, S., Mohammad Moghaddam, M., & Seyyed-Rahmani. (2010). Oil and protein accumulation in soyabean grains under salinity stress. *National Science Biology*, 2(2), 64-67.
24. Ghassemi-Golezani, K., Taifeh-Noori, M., Oustan, Sh., & Moghaddam, M. (2009). Response of soybean cultivars to salinity stress. *Journal of Food, Agriculture & Environment*, **7,** 401-404.
25. Ahmed, M. A., Shengrui, Z., Muhammad, A., Abdulwahab, S. S., Yue, F., Jie, Q., Yanfei, L., Yu, T., Huilong, H., & Bin, L. (2020). Natural variation in fatty acid composition of diverse world soybean germplasms grown in China. *Agronomy*, 10(1), 24. doi:10.3390/agronomy10010024.
26. Hadi, Y., Ahmad, A., Mostafa, G., Reza, F., Mohammad, A., Hosseinpour, F., & Sayyed, S. P. (2012). Effect of salinity on seed oil content and fatty acid composition of safflower (*Carthamus tinctorius* L.) genotypes. *Food Chemistry*, 130, 618-625.
27. Eman, H. A. E. A., Rania, F. E. M. & Engy, S. M. (2021). Alleviation the adverse effects of salinity stress on soybean cultivars by foliar spraying of arginine. *Menoufia Journal of Soil Science*, 6, 343-362. <https://mjss.journals.ekb.eg>.