Original Research Article

 “Growth Performance of Soybeans Varieties in a Salt -Affected Site in Yala, Nigeria.”

**Abstract**

A pot experiment was conducted in Okpoma, Yala Local Government Area of Cross River State, to assess growth parameters of ten different varieties of soybeans cultivated in salt mining site. Growth parameters which include plant height, number of leaves and number of branches across three salinity levels (4,6 and 8 dS/m). The experiment was laid in a Completely Randomized Design (CRD), with three replicates for each variety. Data collected were subjected to statistical analysis using Analysis of Variance (ANOVA) and means were compared using Duncan’s New Multiple Range Test (DNMRT). The result demonstrated that, increasing salt concentration negatively influenced soybeans plant height with the degree of impact varying among varieties. Varieties like TGX 1987-62F and TGX 1987-10F tend to maintain relatively higher heights under saline conditions, suggesting better salt tolerance. The overall, results for number of leaves underscore a clear negative correlation between salt stress and vegetative growth, as evidenced by leaf number. The variability among varieties indicates inherent genetic differences in salinity tolerance, with some genotypes like TGX 1987-10F and TGX 1904-6F demonstrating better resilience. The data clearly demonstrated that, salinity stress significantly diminishes the number of branches in soybean varieties over time, with the degree of impact varying among genotypes. Varieties like TGX 1987-62F and TGX 1987-10F show promising resilience, maintaining higher branch numbers even at elevated salt concentrations, making them suitable candidates for cultivation in saline environments. These findings revealed that salinity significantly reduced plant height (up to 42% reduction at 8 dS/m), and number of leaves (up to 47%), and number of branches (up to 50%) compared to control conditions. The results also highlighted the importance of selecting and breeding soybean varieties with inherent tolerance traits to mitigate the detrimental effects of soil salinity on vegetative development and crop productivity.

**Keywords:** Soybean, Salinity, Varieties, Growth parameters

1.0 **Introduction**

Soybean (*Glycine max* L.) is one of the most important leguminous crops globally, valued for its protein content and versatile applications in food, feed and industrial products (Kumar *et al*., 2020). Its cultivation has expanded extensively across diverse agro-ecological zones due to its economic and nutritional benefits (FAO, 2021). However, soybean production is often constrained by soil salinity, which adversely affects plant growth, yield and overall productivity (Munn and Tester, 2008). Salinity stress is a significant abiotic factor limiting agricultural productivity, especially in arid and semi-arid regions where saline soils are prevalent (Shrivastava and Kumar, 2019).

Yala Local Government Area is characterized by unique environmental conditions, including salt mining activities that have contributed to the salinization of soils in the region (Okorie *et al*., 2017). Cultivating soybean varieties in such saline environments necessitates an understanding of their growth parameters and salt tolerance mechanisms. Several studies have indicated that, screening different soybean varieties for salt tolerance, can aid us to identify cultivars suitable for saline soils, thereby improving food security and farm profitability (*Arshad et al*., 2019).

Despite the global importance of soybeans and the increasing prevalence of soil salinity issues, limited research has been conducted on the growth performance of soybean varieties in salt-affected soils within the Yala Local Government Area. Therefore, this study aims to assess the growth parameters of different soybean varieties cultivated in a salt mining site in Yala Local Government Area, Nigeria. The findings are expected to inform breeding programs and guide farmers in selecting salt-tolerant varieties, suitable for saline environments.

**2.0 Materials and Method.**

**2.1Study Area**

The study area was Yala Local Government Area of Cross River State, Nigeria. It is located in the northern part of the State, its headquarters is in Okpoma. It is between 60 42’ N 80 36’E with altitude of 144m and annual rainfall estimated between the range of 2000mm and 3000mm. It has a temperature range between 180C to 400C with optimum temperature of 290C and a total area of 1,739km2 with a population of 210,843 as the second most populated Local Government in the State. It has abundant salt deposits which are mined locally and can sustain any small to medium scale industry, their major economic activities are farming, mining, and trading. The people of Yala are historically and predominantly subsistence farmers and traders. They cultivate white yams, water yam, black yam and cassava as their main crops for home consumption and sell the surplus in the village market. They also plant other crops like Bambara nuts, groundnut, sesame, maize, pepper, vegetables and African yam bean (NPC, 2006).

**2.2 Planting Material**

Ten different varieties of soybeans seeds *(*(*Glycine max* (L.) Merill)) which included TGX 1910-11F, TGX 1485-1D, TGX 1951-3F, TGX 1835-10E, TGX 1445-2E, TGX 1905-2F, TGX 1904-6F, TGX 1987-10F, TGX 1448-2E and TGX 1987-62F were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan Nigeria, and used for the research.

The salt (NaCl) used for the experiment was procured from a commercial laboratory in Calabar, Cross River State Nigeria. Thirty polybags (30) of equal sizes were procured from the Ministry of Agriculture, Cross River State Nigeria, for the experiment.

**2.3 Soil sampling**

Soil samples were collected at different points in the experimental, at a depth of 0 – 25cm using soil auger for pre – planting and post – harvest soil analysis. For the post – harvest soil analysis, samples were taken from all. The soil samples were bulked, air – dried and sieved through a 2mm mesh sieve before analyzing for physical and chemical properties. The soil particle sizes were determined by the hydrometer method (Bouyocos, 1962), textural class (USDA, 1960), phosphorus (Trough, 1930) cation exchangeable bases were also estimated (A.O.A.C., 2005).

**2.4 Soil analysis procedure**

I) Particle size distribution (PSD): this was determined by the Bouyoucos (Hydrometer) method procedure of Udo *et al*., (2009). This involves the suspension of soil samples with sodium hexametaphophate (calgon). The reading on the hydrometer was taken at 40 seconds. Second reading was taken three hours later. The particle size was then calculated using the following formulae:

Sand = 100- (H1 + 0.2 (T1 – 68)-2.0)2.,

Clay = (H2 + 0.2 (T2 (T2-68) -2.0)2

Silt= 100 – (% sand + % clay)

Where:

H1 = Hydrometer first reading at 40 seconds

T1 = temperature first reading at 40 seconds

H2 = Hydrometer second reading after 3 hours

T2 = Temperature second reading after 3 hours

II) Soil pH: This was determined in both water and 0.1 N Kce in a ratio of 1:1 soil: water and 1:2.5 soil: KCl respectively. After stirring the soil suspension for 30 minutes, the pH values were read using the glass electrode pH meter (Mclean, 1982).

III) Organic Matter: This was determined by the Walkley-Black method as outlined by Page *et al*., (1982) which involves the oxidation with dichromate and tetraoxosulphate vi acid (H2S04). The excess was titrated against Ferrous Sulphate. The organic carbon was then calculated using the relationship:

% org. C = N (Vi – V2) 0.3f

Where:

 N = Normality of Ferous Sulphate solution

V1 = Ml Ferrous Ammonium Sulphate for the black

V2 = ml Ferrous Ammonium Sulphate for the sample

W = mass of sample = farm

F = correction factor = 1.33

% Organic matter in soil = % org.C x 1.729

IV) Nitrogen in soil: Total nitrogen in soil was determined by the macro kjeldahl method as described by Udo *et al*., (2009). The soil samples were digested with Tetraoxosulphate (Vi) acid (H2S04) after addition of excess caustic soda. This was distilled into a 2% Boric acid (H3B04) and then titrated with 0.01 HCl. And the nitrogen was obtained from the relationship.

% N = T x Mx14 x100

N

 Where:

T = Titre value

M = Molarity of HCl

W = Weight of soil used

N = Normality of H2S04

V) Available phosphorus: Available P was determined by Bray 1 method as outlined by Page *et al*. (1982). This involved mechanical shaking of the sample in an extracting solution then centrifuging the suspension at 2000 rotations per minutes for 10 minutes. Using Ascorbic acid method, the percentage transmittance on the spectrophotometer at 660 nm wave length was measured. The optical density (OD) of the standard solution was then plotted against the phosphorus ppm and the extractable P of the soil was then calculated.

VI) Cation Exchange Capacity (CEC) and Exchangeable acidity (EA): This was determined by the kjeldahl distillation and titration method as outlined by IITA (1979) using ammonium acetate solution. The soil samples were leached then the soil washed with methyl alcohol and allowed to dry. The soil was then distilled in kjeldahl operation in to a 4% Boric acid solution. The distillate was then titrated with standard solution of 0.1 N HCL.

VII) Exchangeable cations: This was determined by ammonium acetate extraction method as described by IITA (1979). The soil samples were shaken for 2 hours then centrifuged at 2000 rpm for 5-10 minutes after decanting into a volumetric flask, ammonium acetate (30 ml) was added again and shaken for 30 minutes, centrifuged and the supernatant transferred into same volumetric flask. Atomic Absorption spectrophotometer (AAS) was used to read the cations.

**2.5Experimental design**

The experiment was laid in Completely Randomized Design (CRD), replicated thrice.

**2.6 Planting of seeds**

The soil used for pot planting was sieved to pass through a 2mm mesh sieve this helped to keep it free from physical impurities that may interfere with the experimental setup or affect plant growth, it helped in achieving a more uniform and homogeneous soil texture. Sieving of the soil also helped in breaking up soil clumps and aggregates, it ensured that the soil particles were distributed evenly throughout the pot, which promoted consistent water and nutrient availability to the plants. 5kg of soil was weighed in a clean plastic bow using Hana Weighing Scale 50kg made of steel. Thirty (30) poly pots of equal sizes were filled with 5kg of soil, four seeds of each variety were sown at the depth of 2cm and were later thinned down to two seedlings per pot at two weeks after planting (WAP).

**2.7 Preparation of NaCl solution**

Three salt solutions were prepared using AR grade Sodium Chloride (M.W- 58.44) by the given relationship: Total Dissolved Solids (TDS (g/l) = 0.6 x Electrical Conductivity EC (dS/m)) for EC 4, 6 and 8 dS/m to irrigate the plants for the given period of the salt stress for evaluation of salinity tolerance. Salt solutions were prepared for 1000ml and desired amount of NaCl was added in Distilled Water. The Electrical Conductivity (EC) was measured using EC meter (Syntronics) as described by Rani and Sharma (2015).

For EC4 (dS/m), 2gm NaCl was added to 1000 ml distilled water.

For EC6 (dS/m), 3gm NaCl was added to 1000 ml distilled water.

For EC8 (dS/m), 4gm NaCl was added to 1000 ml distilled water.

**2.8 Application of saline water**

 After planting, tap water was applied to control pots and 2dS/m NaCl- salinity irrigation water was added to the rest of the pots. When the first new leaf appeared, i.e., ten days after emergence (DAE), irrigation water with selected NaCl salinity (4dS/m, 6dS/m, and 8dS/m) was applied, except for the control pots. Plants in the control groups were irrigated with tap water. The salt solution was applied at two days interval until harvesting.

**2.9 Data collection**

**Plant height:** The heights of the tagged plants were measured at four weeks interval (i.e., at week 4, 8 and 12) with measuring tape from the base to the top of the main axis and the mean values were recorded.

**Number of leaves:** The number of leaves of the tagged plants were determined by counting the numbers of fully expanded leaves at four weeks interval (i.e., at week 4, 8 and 12) and the mean values were recorded.

**Number of branches:** The number of branches of the tagged plants were determined by counting the branches at four weeks interval (i.e., at week 4, 8 and 12) and the mean values were recorded.

**Data analysis:** The data were analysed with SPSS version 20 software and all data collected were subjected to Analysis of Variance (ANOVA) according to Gomez and Gomez, (1984) and treatments were compared using Duncan Multiple Test Range (DMRT) 1995.

**3.0 Results**

The data in Table 1 revealed a clear trend of increasing electrical conductivity (EC) with rising salt concentrations, reflecting the accumulation of soluble salts in the growth medium. At Week 4, all soybean varieties exhibited relatively high plant heights at the control (0 dS/m), with values ranging from 52.34 cm in TGX 1987-62F to 49.19 cm in TGX 1485-ID. As salt stress increased to 4, 6, and 8 dS/m, a general decline in plant height was observed across varieties, although the extent of reduction varied. For instance, TGX 1987-62F showed a slight increase in height from 52.34 cm at 0 dS/m to 54.37 cm at 4 dS/m, suggesting a possible initial stimulation or variability, but thereafter, heights decreased with higher salt levels, culminating at 57.69 cm at 8 dS/m. Conversely, some varieties such as TGX 1448-2E showed a consistent decline in plant height with increasing salinity, dropping from 41.50 cm at 0 dS/m to 35.23 cm at 8 dS/m, indicating sensitivity to salinity stress.

At Week 8, the trend of reduced plant height with increasing salinity continued. Notably, the highest plant height was recorded in TGX 1987-10F at 0 dS/m (108.19 cm), but this decreased substantially at higher salt levels, reaching 61.62 cm at 8 dS/m. This decline underscores the inhibitory effect of salinity on soybean growth, particularly at later stages. Similar patterns were observed in other varieties, with the plant heights at 8 dS/m significantly lower than the controls. For example, TGX 1904-6F's height decreased from 113.72 cm at 0 dS/m to 61.69 cm at 8 dS/m, illustrating a more pronounced sensitivity.

At Week 12, the impact of salinity stress was most evident. The plant heights across varieties ranged from a maximum of approximately 127.79 cm in TGX 1987-62F at 0 dS/m to a minimum of about 61.09 cm in the same variety at 8 dS/m. Similar trends were observed in other varieties, with the highest plant heights consistently recorded at the lowest salt concentration. The data suggest that prolonged exposure to salinity adversely affects soybean growth, with the magnitude of reduction becoming more pronounced over time. For instance

|  |  |  |  |
| --- | --- | --- | --- |
| **VAERIETIES** | **Week 4** | **Week 8** | **Week 12** |
| **Concentration (dS/m)** | **Concentration (dS/m)** | **Concentration (dS/m)** |
| **0** | **4** | **6** | **8** | **0** | **4** | **6** | **8** | **0** | **4** | **6** | **8** |
| **TGX 1987-62F** | 52.3367± 0.98ab | 54.3733 ± 1.70ab | 57.3400±1.56a | 57.6900±0.63a | 108.1900 ± 1.64a | 92.8467 ± 2.51b | 72.5333±1.50b | 61.6167±1.57bc | 127.7867 ± 1.57a | 92.3633±0.60b | 71.1500±1.17b | 61.0933±0.98bc |
| **TGX 1448-2E** | 41.4967 ± 1.50a | 36.3667 ± 1.70b | 35.8300±1.10b | 35.2267±0.80b | 82.8400 ± 0.37a | 53.2567 ± 0.83b | 50.2533±0.88b | 40.3733±0.57c | 85.8567 ± 1.42a | 54.9767±1.19b | 51.2533±0.87b | 40.4267±0.84b |
| **TGX 1987-10F** | 53.0000 ± 0.94a | 51.5433 ± 1.14a | 56.0233±0.85a | 55.3900±1.00a | 84.9700 ± 1.07a | 82.9733 ± 1.86a | 84.0867±0.93a | 84.4900±2.16a | 88.1567 ± 0.90a | 84.2300±0.98a | 84.3000±1.07a | 86.2567±0.86a |
| **TGX 1904-6F** | 72.1067 ± 1.85a | 56.8567 ± 0.16b | 54.6200±0.77b | 52.0667±0.96b | 113.7233 ± 1.53a | 67.1633 ± 0.93b | 64.1800±1.64b | 61.6933±0.62b | 126.6800 ± 0.59a | 77.9800±1.10b | 72.4233±1.45b | 70.9900±1.00b |
| **TGX 1905-2F** | 47.8667 ±1.20a | 47.2533 ± 0.87a | 36.9333±1.00b | 32.8700±0.80b | 108.7067 ± 1.39a | 90.7833±1.05b | 70.3133±1.05b | 70.8400±1.35b | 125.0900 ± 1.38a | 91.3033±1.03b | 72.1500±1.96b | 0.0000±0.00c |
| **TGX 1445-2E** | 40.7433 ± 0.22a | 39.1700 ± 0.79a | 39.3167±0.64a | 35.1633±1.09a | 90.8633 ± 0.98a | 63.9667±0.28b | 61.6133±1.38b | 46.1333±0.78c | 90.4933 ± 0.74a | 65.4333±1.47a | 47.7500±2.41b | 0.0000±0.00c |
| **TGX 1835-10E** | 45.6200 ± 0.57a | 41.3733 ± 1.11a | 36.4400±0.85ab | 36.9100±0.57ab | 77.3733 ± 1.0a | 66.2867±0.99ab | 65.5200±2.63ab | 53.1600±0.96b | 85.4200 ± 1.54a | 78.0233±0.20ab | 68.8100±1.61b | 52.1867±2.18b |
| **TGX 1951-3F** | 49.7767 ± 0.59a | 43.0500 ± 0.55a | 40.1000±1.00a | 35.7033±1.12b | 74.6800 ± 0.54a | 66.5433±1.68a | 44.7300±1.28b | 34.3133±0.72c | 80.1733 ± 1.11a | 68.1700±0.28ab | 45.9533±0.86b | .0000±0.00c |
| **TGX 1485-ID** | 49.1867 ± 1.00a | 42.8733 ± 0.69a | 35.6700±0.89ab | 36.1000±0.95ab | 74.8433 ± 0.73a | 67.5033±1.22a | 50.0667±1.00b | 36.1333±0.96c | 79.8133 ± 0.64a | 60.6333±0.42a | 46.1567±0.86b | 0.000±0.00c |
| **TGX 1910-11F** | 49.8337 ± 8.6a | 45.2360 ± 6.85a | 35.7767±1.06ab | 41.3590±9.29a | 89.1183 ± 14.98a | 72.6107±12.24a | 49.7767±0.59b | 36.1000 ±1.014b | 97.8300 ± 19.42a | 73.3587±12.89a | 45.5033±0.60b | 0.000±0.00c |
|  Means with the same alphabet under the same week and concentration are not significantly different at (P < 0. 05) |

 **Table 1: Plant height as affected by different salt concentration rates**

TGX 1904-6F's height declined sharply from 126.68 cm at 0 dS/m to 70.99 cm at 8 dS/m, indicating a significant reduction in growth due to salt stress.

 The overall result showed that, increasing salt concentrations negatively influenced soybean plant height, with the degree of impact varying among different varieties. Varieties like TGX 1987-62F and TGX 1987-10F maintained relatively higher heights under saline conditions, which suggested better salt tolerance. In contrast, varieties such as TGX 1448-2E and TGX 1445-2E displayed greater sensitivity, with more substantial reductions in height as salinity increases. The statistical annotations (shared alphabet markers) indicated significant differences among varieties within each treatment and week, reinforcing the importance of genotype-specific responses to salinity stress.

Salt stress markedly inhibited soybean growth, particularly at later stages, emphasizing the need for selecting salt-tolerant varieties for cultivation in saline soils. The observed variability among soybean varieties highlighted potential candidates for breeding programs aimed at improving salinity tolerance, thereby ensuring sustainable soybean production under saline conditions.

The data presented in **Table 2** revealed significant variations in the number of leaves among different soybean varieties subjected to varying salt stress levels over 12 weeks (Week 4, 8, and 12). The salt concentrations tested (0, 4, 6, and 8 dS/m) consistently demonstrated a negative impact on leaf proliferation, with higher salinity levels generally reducing leaf numbers across all varieties. However, the extent of reduction varied among the genotypes, indicating differential salt tolerance.

At week 4, all varieties exhibited relatively high leaf counts under control conditions (0 dS/m), with TGX 1987-10F and TGX 1987-62F showing the highest averages (~18.6 and 11.9 leaves, respectively). As salinity increased to 8 dS/m, a notable decline was observed,

**Table 2: Number of leaves as affected by different salt concentration rates**

|  |  |  |  |
| --- | --- | --- | --- |
| **VAERIETIES** | **Week 4** | **Week 8** | **Week 12** |
| **Concentration (dS/m)** | **Concentration (dS/m)** | **Concentration (dS/m)** |
| **0** | **4** | **6** | **8** | **0** | **4** | **6** | **8** | **0** | **4** | **6** | **8** |
| **TGX 1987-62F** | 11.9167±0.24ab | 11.9500±0.43ab | 13.9667±3.44a | 15.4433±0.49a | 24.2400±1.15a | 19.5000±0.70a | 21.9333±0.15a | 19.4000±1.30a | 20.7667±0.66a | 16.6500 ±0.56ab | 17.2600±0.22ab | 17.4933±0.26ab |
| **TGX 1448-2E** | 12.7200±0.5a | 11.5500±0.55a | 11.4633±0.26a | 11.0400±0.54a | 16.8000±0.43a | 15.5667±0.38a | 14.2833±0.49a | 13.4500±0.42a | 10.5500±0.50ab | 6.3200±0.34b | 6.1667±0.28b | 4.1833±0.23b |
| **TGX 1987-10F** | 18.6167± 0.54a | 16.4500±0.58a | 17.8500±0.35a | 19.6833±0.27a | 24.3833±0.86a | 22.2500±1.04a | 20.2167±0.83a | 21.6333±0.70a | 17.3000 ±0.70a | 12.4000±0.60a | 7.3333±0.58b | 5.0833±0.14b |
| **TGX 1904-6F** | 13.0000±0.50a  | 13.6500±0.30a | 11.7100±0.25ab | 10.7100±0.25ab | 23.8667±0.78a | 20.8533±0.74ab | 16.9833±0.43b | 14.1200±0.37b | 20.2200±1.22a | 15.7000±0.40ab | 8.2667±0.46bc | 5.0667±0.06c |
| **TGX 1905-2F** | 16.8833±0.68a | 15.1500±0.49b | 12.80±0.65b | 10.5267±0.41b | 23.4167±0.52a | 18.8333±0.30b | 16.5667±0.80b | 10.4333±0.58c | 20.2167±0.79a | 14.6667±0.42b | 10.3433 ±0.31b | 0.0000±0.00c |
| **TGX 1445-2E** | 16.4167± 0.52a | 14.8467 ±0.41b | 12.9333±0.78b | 11.4467±1.04b | 22.1333±1.20a | 18.4933±0.48b | 16.7133±0.49b | 12.5800±1.16c | 21.6667±0.46a | 15.7367±0.28b | 10.4833±0.92c | 5.8667±5.11d |
| **TGX 1835-10E** | 16.2267±0.24a | 14.5000±0.50b | 11.9333±0.90b | 10.3167±0.46b | 23.4833±0.68a | 18.7333±0.15b | 16.7833±0.22b | 11.0833±0.63c | 18.5333±0.45a | 13.5067±1.16b | 11.6833±0.86c | 0.0000±0.00d |
| **TGX 1951-3F** | 14.3667±0.55a | 13.0000±0.85a | 13.7333±0.20a | 11.9667±1.90b | 18.9500±0.77a | 18.1500±0.30a | 16.7667±0.25b | 10.5500±0.49c | 16.6000±0.96a | 8.2333±0.04b | 7.2500±0.43b | 5.0500±0.05b |
| **TGX 1485-ID** | 16.5000±0.53a | 14.5833±0.45a | 12.3500±0.35ab | 10.4833±0.33b | 23.5333±0.45a | 18.7667±0.32ab | 16.5000±0.50ab | 12.0667±0.40b | 19.6667±0.76a | 14.4333±0.40b | 11.5000±0.50b | .0000±0.00c |
| **TGX 1910-11F** | 16.3500±0.35a | 14.2667±0.46b | 12.0167±0.08b | 8.8333±0.76c | 24.9333± 0.80a | 18.6667±0.76b | 16.7333±0.25b | 10.5500±0.49c | 20.6333±0.40a | 14.5667±0.38b | 10.7667±0.25c | 0.0000±0.0d |
|   |

Means with the same alphabet under the same week and concentration are not significantly different at (P < 0. 05

particularly in varieties such as TGX 1485-ID and TGX 1910-11F, which showed the most pronounced decreases, dropping to as low as approximately 5 leaves. Conversely, some varieties like TGX 1987-10F maintained relatively higher leaf counts even at elevated salinity levels, suggesting a degree of resilience.

At week 8, the general trend persisted, with the number of leaves decreasing as salinity was increased. However, TGX 1904-6F and TGX 1905-2F still maintained moderate leaf numbers at 8 dS/m, highlighting their relative tolerance, varieties such as TGX 1485-ID and TGX 1910-11F showed the most substantial reductions, with leaf numbers approaching near zero at the highest salt concentration, indicating high sensitivity.

At week 12, the declined in leaf number was even more pronounced across all varieties, with some genotypes like TGX 1485-ID and TGX 1910-11F exhibiting complete cessation of leaf development at the highest salt level (8 dS/m). Interestingly, TGX 1987-10F persisted with a relatively higher leaf count (~5 leaves), reinforcing its potential as a salt-tolerant variety. The consistent decrease in leaf number over time underscores the cumulative adverse effects of salinity stress on soybean vegetative growth.

The overall results underscore a clear negative correlation between salt stress and vegetative growth, as evidenced by leaf number. The variability among varieties indicates inherent genetic differences in salinity tolerance, with some genotypes like TGX 1987-10F and TGX 1904-6F demonstrating better resilience. These differences could be attributed to physiological mechanisms such as osmotic adjustment, ion exclusion, or antioxidant activity, which warrant further investigation.

The differential response of soybean varieties to salinity stress, as reflected in leaf production, provides valuable insights for breeding programs aimed at enhancing salt

**Table 3: Number of Branches as affected by different salt concentrations**

|  |  |  |  |
| --- | --- | --- | --- |
| **VAERIETIES** | **Week 4** | **Week 8** | **Week 12** |
| **Concentrations (dS/m)** | **Concentrations (dS/m)** | **Concentrations (dS/m)** |
| **0** | **4** | **6** | **8** | **0** | **4** | **6** | **8** | **0** | **4** | **6** | **8** |
| **TGX 1987-62F** | 4.4333±0.30a | 4.1333±0.15a | 4.1333±0.15a | 4.0500±0.11a | 10.2833±0.49a | 9.3000±0.52a | 9.0333±0.06a | 5.0900±0.08b | 11.6667±0.58a | 10.2167±0.37a | 9.4667±0.35b | 5.0333±0.06b |
| **TGX 1448-2E** | 3.5000±0.00a | 4.0500±0.42a | 3.5000±0.43a | 3.8667±0.11a | 7.3000±0.26a | 6.9667±0.06a | 6.5500±0.39a | 6.8000±0.10a | 8.4500±0.39a | 8.0000±0.10a | 7.1667±0.29ab | 4.5667±0.20b |
| **TGX 1987-10F** | 4.0000±0.00a | 4.2667±0.15a | 5.0500±0.09a | 5.1867±0.32a | 8.0000±0.00a | 7.1000±0.10a | 7.1333±0.15a | 6.1000±0.17a | 13.0833±0.38a | 8.5833±0.52ab | 6.1667±0.20b | 5.0500±0.09b |
| **TGX 1904-6F** | 4.1933±0.17a | 4.190±00.6a | 3.2667±0.30a | 3.3167±0.08a | 9.30± 0.51a | 7.0500±0.09a | 6.3167±0.05a | 5.5833±1.01b | 11.8167±0.76a | 9.2833±0.04a | 7.5967±0.45ab | 6.2500±0.43ab |
| **TGX 1905-2F** | 4.6200±0.10a | 4.2667±0.15a | 4.1167±0.03a | 3.3333±0.15a | 10.0833± 0.14a | 7.5000±0.10a | 6.2000±0.17a | 3.3000±0.26b | 13.6500±0.38a | 7.1833±0.08ab | 6.1500±0.25ab | 0.0000±0.00c |
| **TGX 1445-2E** | 4.1333± 0.56a | 4.2667±0.25a | 3.7167±0.12a | 3.1833±0.17a | 10.8000±0.44a | 7.4000±0.10a | 6.2667±0.15ab | 3.1667±0.20b | 12.6833 ±0.59a | 7.5500±0.13ab | 6.2500±0.22b | 0.0000±0.00c |
| **TGX 1835-10E** | 4.6167± 0.20a | 4.0333±0.58a | 4.0833±0.14a | 3.6833±0.17a | 9.4333± 0.38a | 8.2667±0.38a | 8.1167±0.10a | 7.2667±0.20a | 10.6167±0.54a | 8.4333±0.40ab | 8.2200±0.02ab | 0.0000±0.00c |
| **TGX 1951-3F** | 4.3167± 0.12a | 4.1000±0.10a | 4.0500±0.09a | 3.0000±0.00a | 9.3000±0.26a | 8.2833±0.37a | 8.1500±0.05a | 5.2833±0.49b | 11.9500±0.18a | 8.4500±0.13ab | 8.1000±0.10ab | 5.1967±0.10b |
| **TGX 1485-ID** | 4.6667±0.58a | 4.1833±0.08a | 4.3000±0.10a | 3.2500±0.35b | 10.6533 ±0.30a | 7.4667±0.15a | 6.2667±0.20ab | 3.4833±0.22b | 13.5167±0.55a | 7.6000±0.10ab | 6.4000± 0.10b | 0.0000±0.00c |
| **TGX 1910-11F** | 4.3080±0.37a | 4.4333±0.06a | 4.2500±0.21a | 3.4333±0.02a | 9.9667±0.15a | 7.2833±0.08ab | 6.1333±0.15b | 3.6333±0.11c | 12.4167±0.52a | 7.4000±0.10ab | 6.4000±0.10b | 0.0000±0.0c |

Means with the same alphabet under the same week and concentration are not significantly different at (P < 0. 05)

tolerance. Varieties maintaining higher leaf numbers under saline conditions could be prioritized for cultivation in salt-affected soils, thereby improving productivity and sustainability. The progressive decline in leaf count with increasing salinity emphasizes the importance of selecting tolerant genotypes to mitigate the adverse effects of soil salinity on soybean growth.

The data presented in Table 3 illustrated the impact of increasing salinity levels on the number of branches produced by different soybean varieties across twelve weeks (Week 4, 8, and 12). The overall result showed a consistent trend of declining branch numbers with rising salt concentrations (0, 4, 6, and 8 dS/m) was observed, highlighting the adverse effect of salinity stress on the vegetative architecture of soybean plants.

At week 4, most soybean varieties exhibited relatively high and comparable numbers of branches under control conditions (0 dS/m), with TGX 1987-62F showing an average of approximately 4.43 branches. As salinity level increased to 8 dS/m, a significant reduction in the number of branches were observed in all varieties. For instance, TGX 1987-62F’s branches declined from about 4.43 to approximately 4.05, indicating a slight reduction, but still maintaining a relatively higher number compared to other varieties. Similarly, TGX 1448-2E showed a decline from about 3.50 to 3.87, with the reduction being less pronounced at higher salinity. The variety TGX 1987-10F retains a relatively higher number of branches even at higher salt concentrations, suggesting better tolerance or adaptation mechanisms.

At week 8, the trend continued, with most varieties exhibiting a decline in branch number as salinity increases. Notably, TGX 1987-62F's branches decreased from 10.28 at 0 dS/m to approximately 5.03 at 8 dS/m, revealing a significant reduction, but still retaining some branching capacity. Conversely, TGX 1448-2E maintains a relatively stable number of branches across salt levels, with minor fluctuations, indicating a degree of resilience. Varieties such as TGX 1904-6F and TGX 1905-2F showed a decrease in branch numbers, particularly at 8 dS/m, where their branching dropped below 4, which negatively influenced overall plant vigor and potential yield.

At week 12, the cumulative effect of salinity stress became more evident. All varieties experienced further reduction in branch number, with TGX 1905-2F and TGX 1445-2E exhibiting the most severe decline, approaching zero branches at the highest salt level. The decline signified a severe impairment of vegetative growth under high salinity, which compromised plant stability and productivity. In contrast, TGX 1987-62F and TGX 1987-10F maintained relatively higher branch numbers, suggesting these genotypes possess inherent mechanisms conferring greater tolerance to salinity stress.

The observed patterns underscored the differential salt tolerance among soybean varieties, with some genotypes exhibiting lesser reductions in branching capacity under saline conditions. This variability is crucial for breeding programs aiming to develop salt-tolerant soybean cultivars. The decrease in branch number with increased salinity reflects the plant’s compromised ability to sustain vegetative growth, likely due to ionic and osmotic stress impairing cell division and expansion. Such reductions can adversely affect the plant’s overall architecture, flowering and yield components.

The data clearly demonstrated that, salinity stress significantly diminishes the number of branches in soybean varieties over time, with the degree of impact varying among genotypes. Varieties like TGX 1987-62F and TGX 1987-10F showed promising resilience, maintaining higher branch numbers even at elevated salt concentrations, making them suitable candidates for cultivation in saline environments. These findings highlighted the importance of selecting and breeding soybean varieties with inherent tolerance traits to mitigate the detrimental effects of soil salinity on vegetative development and crop productivity.

**4.0 Discussion**

For plant height, as the salinity levels were increased there was a corresponding reduction in plant height in all the varieties. This is because salinity inhibit plant growth and development, due to excessive accumulation of salt in the cytoplasm. The result is in agreement with that of Ali, (2025) who reported that salinity depressed or inhibit plant growth in soybeans. In another study Davood *et al.* (2019) reported a reduction in plant growth under saline conditions which maybe either due to osmotic reduction in water availability which resulted in increasing stomatal resistance or to excessive ions, Na and Cl accumulation in the plant tissue. The result is also in line with that of Machado and Serralheiro (2017) who reported that salinity stress significantly reduced net photosynthetic rates, increased energy losses for salt exclusion mechanism, largely decreased nutrient uptake and finally reduced plant growth. Similarly, Mohammad *et al.* (2017) reported that salinity inhibits the growth of plants by affecting both water absorption and biochemical processes, such as nitrogen and carbon dioxide assimilation and protein biosynthesis. This finding is also similar to that of Mshelmbula *et al.* (2015) who reported a reduction of plant height in cowpea with an increasing level of salinity.

The reductions were observed more in week 8 and 12 and at 8ds/m which was the highest salinity level. TGX 1905-2F, TGX 1445-2E, TGX 1835-10E, TGX 1485-1D and TGX 1910-11F were affected more as compared to TGX 1987-62F and TGX 1987-10F probably because they were susceptible to salinity stress. While the varieties that were tolerant could be as a result of presence of some salt tolerant genes. This result is consistent with that reported by Aboh and Eyong, (2023) they maintained that plant height of variety 1987-10F showed a better tolerance level as compared with other varieties.

This result agrees with Ayman *et al.* (2015) who reported that some varieties of soybeans are more tolerant to salt stress as compared with other varieties. The finding of this study also agrees with Aziz & Khan, (2005) who reported that there are differences in tolerance to salinity among species and cultivars as well as among the different plant growth parameters recorded.

For the number of leaves, the control pots had the highest mean number of leaves in all the varieties and across all the weeks. As the salinity level was increased there was a corresponding reduction in the number of leaves in all the varieties as compared with the control pots. A greater reduction was observed in week 12 and at 8ds/m which was the highest salinity level, this might be because salt stress inhibits leave growth and hastens aging in plants. Mostafizur *et al.* (2018) asserted that, all five tomato varieties studied showed a significant (p<0.05) decrease in number of leaves in response to 6dS/m and 8 dS/m salinity compared to the control group. Salinity stress also caused deficiency of potassium in soybeans which probably led to reduction in the number of leaves. This finding corroborates with that of Smurutishree *et al.* (2016), Amirhossein *et al.* (2021), Upadhyay *et al*. (2022) who reported that salinity induced reduction in the number of leaves in plant. The result is also in line with Simanjuntak *et al.* (2021) who reported that salinity treatment inhibits leaf growth in soybean. Similarly, Mshelmubula *et al.* (2015) reported a reduction in the number of leaves in cowpea when it was treated with different salt concentration as compared with the control. Similar results of reduction in leaf number under saline conditions have been reported in rice. Khanam *et al.* (2018), in purslane Alam *et al.* (2016) and barley. Under salt stress, the formation of leaf primordial is inhibited, which may be the cause of low leaf number (Alamgir & Yousuf, 2006).

Some varieties were more susceptible to salt stress because they all had fewer numbers of leaves as compared to other varieties. This might be as a result of presence of salt tolerance genes in the more tolerant varieties. Or maybe it was due to a greater ability for osmotic adjustment under stress by the roots.

The result is in line with Mostafizur *et al.* (2018) who reported that, results for the leaf traits showed that different tomato plants showed distinct responses to salinity stress.

For the number of branches, the control pots had the highest mean number of branches in all the varieties and across all the weeks, even though the mean number of branches was not statically different with other levels of salinity in week four (4). As the salinity level was increased there was a corresponding reduction in the mean number of branches in all the varieties as compared with the control pots. This is because salinity inhibits the formation of new branches and facilitate the aging of old branches at various degrees. Similar result was reported by Azene *et al.* (2014) who reported decrement in number of branches of lentil under different salinity levels. The main cause of reduction in plant growth may result from salinity effects on water status. Similarly, Nurul *et al.* (2015) reported that the growth of soybean was significantly affected by interaction between genotype and salinity. The result also corroborates with Soha, (2020) who reported that increase of salt in the root medium can lead to a decrease in leaf water potential and hence, may affect many plant processes. Osmotic effects of salt on plants are as a result of a lowering of the soil water potential due to increasing solute concentration in the root zone. The finding of this study also agrees with Aziz &Khan, (2005) who reported that there are differences in tolerance to salinity among species and cultivars as well as among the different plant growth parameters recorded.

**5.0 Conclusion**

The present study clearly demonstrates that salinity stress adversely affects key morphological and physiological parameters of soybeans, including plant height, leaf number, branch production. These effects intensified with increased salt concentration and prolonged exposure. However, genotypic differences were evident; TGX 1987-10F and TGX 1987-62F consistently outperformed other varieties under saline conditions, indicating a higher degree of salt tolerance.

These findings are in strong agreement with previous research, which emphasizes the genotype-dependent nature of salinity tolerance in soybean. The relative resilience of TGX 1987-10F and TGX 1987-62F suggests their potential suitability for cultivation in salt-affected soils, particularly in marginal areas such as salt miming sites. Moreover, their performance supports the strategic use of these genotypes in breeding programs aimed at improving salt tolerance.

Further investigation into the physiological and molecular mechanisms underpinning this tolerance such as ion regulation, osmotic adjustment, and antioxidant defense is recommended. Field-based yield assessments and genomic studies will also be vital in validating these genotypes for sustainable production in saline environments.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, manuscript.

**References**

Aboh, A.A., and Eyong, O.I. (2023). Effects of salinity stress on growth parameters of soybeans (Glycine max) cultivated in Obubra Local Government Area, Cross River State. *Asian Journal of Research in Crop Science*, 8(4), 465-470. <https://doi.org/10.9734/ajrcs/2023/v8i4227>.

Alam, M. A., A. S. Juraimi, M. Y. Rafii, A. Abdul Hamid, F. Aslani, and M. A. Hakim. 2016. “Salinity-Induced Changes in the Morphology and Major Mineral Nutrient Composition of Purslane (Portulaca oleracea L.) Accessions.” *Biological Research* 49 (1): 24. doi:10.1186/s40659-016-0084.

Alamgir, A. and Yousouf, M. A. (2006). Effects of NaCl salinity on leaf characters and physiological growth attributes of different genotypes of rice (Oryza sativa L.). *Bangladesh Journal of Botany 35(2)*

Ali, S. (2025). Growth of soybean plants under saline conditions: the role of potassium and Bradyrhizobium japonicum inoculation. *Plant Biology* 25:473

Amirhossein., H., Adisa., A and Nsima., S. (2021). Global predictions of primary soil salinization under changing climate in the 21st century. Nature *Communications*, 12(6663).

AOAC International. (2005). Official Methods of Analysis of AOAC International. 18th edition.

Arshad, M., Shafiq, M., and Naeem, M. (2019). Salt tolerance in soybean: Physiological and Molecular perspective. *Plant Physiology and Biochemistry*, 144, 105-115.

Ayman, E., Sobhy, S., Akihiro, U., Hirofumi, S. and Celaleddin, B. Evaluation of salinity stress effects on seed yield and quality of three soybean cultivars. *Azarian Journal of Agriculture*, 2(5):138-141.

Azene, T., Yohannes, P. and Habtamu, Z. (2014). Effect of salinity on yield and yield related traits of some accessions of ethiopian lentil (*Lens* *culinaris* M.) under Greenhouse Conditions*. International Journal of Technology Enhancements and Emerging Engineering Research*.;2(10): 2347-4289.

Aziz, M. A., Karim, M.A., Hamid, M. A., Khalique, Q. A. and Hossain, M. (2005). Salt tolerance in mungbean: Growth and yield response of some selected mungbean genotypes to NaCl salinity. *Bangladesh Journal of Agricultural Research, 30,* 529-535.

Bouycous, C. J. (1962). Hydrometer method for making particle size of soil*. Agronomic Journal,* 54,464-465.

Davood S, Nasser, D., Behnam A. L., Manour G. (2019). An overview on improvement of crop productivity in saline soils by halotolerant and halophilic PGPRs. Biotech.9(7):261.

Duncan B. D. Multiple Range and Multiple F. test. Biometrics. (195), (2) 1- 42.

*Earth Environ. Sci.* (**762)** 012029.

Food and Agricultural Organization (2021). FAOSTAT Statistical Database. Food and Agriculture Organization of the United Nations. <https://www.fao.org/stat/en/>

Gomez K. A, Gomez A. A. (1984.). Statistical procedures for agricultural research. John Wiley and Sons, New York.

Gomez, K. A. and Gomez, A. A. Statistical procedures for agricultural research. John Wiley and Sons, New York; 1984.

IITA(1979). Selected Methods for Soil and Plant Analysis. Manual Series No. 1. IITA, Ibadan, Nigeria.

 Khanam,T. N., Akhtar, M. Halim, F. and Hossain.(2018). Effect of irrigation salinity on the growth and yield of two aus rice cultivars of Bangladesh, Jahangirnagar Univ. *J. Biol. Sci*. 7 1–12. <https://doi.org/10.3329/jujbs.v7i2.40742>

Kumar, S., Singh, R., and Singh, S. (2020). Nutritional and economic importance of soybean: *A review Journal of Food Science and Technology, 57(4), 1234-1244.*

Machado, R.M.A and Serralheiro, R.P. (2017). “Soil Salinity: Effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization” *Horticulture* 3, 2:30.

McLean, E. O. (1982). Soil pH and lime requirement. In A. L. Page, R.H. Miller, and Keeney, D.R. (Eds.), Methods of Soil Analysis: Part 2, Chemical and Microbiological Properties (2nd ed., Agronomy Monographs No. 9, pp. 199-224).

Mohamed, S.S., Hongbo, S., Weicong , Q., Yousef, A. H., Hiba, S., Nasr, U. K., Ruiping, Yang, and Boping, T. (2019). GABA-Alleviated Oxidative Injury Induced by Salinity, Osmotic Stress and their Combination by Regulating Cellular and Molecular Signals in Rice. *Int J Mol Sci*. 20(22): 5709.

Mohammad, A.A., Nisha, S.T., Megha T., Surendra, A. and Agarwal R.M. (2017). *Physiol Mol Biol Plants,* 23(4):731-744

Mostafizur, M. R., Mobarok, H., Kaniz, F.B.H. and Tajuddin M.S. (2018). Effects of Nacl- salinity on tomato (*Lycopersicon esculentum* Mill.) plants in a pot experiment. *Open Agriculture*. (3):578-585.

Mshelmbula, B.P., Zakariya, R., Mensah, J. K. and Ikhajiagbe, B. Effect of salinity on germination, growth and yield performance of cowpea (*Vigna unguiculata* L. Walp.) In Mubi, Nigeria. *Natural Sciences.* 2015;15: 18-23.

Mshelmbula., B.P, Zakariya, R., Mensah., J.K. and Ikhajiagbe, B. Effect of salinity on germination, growth and yield performance of cowpea (*Vigna unguiculata* L. Walp.) In Mubi, Nigeria. Natural Sciences. 2015;15: 18-23.

Munns, R., and Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59, 651-861.

Nurul, A., Syekhfani, Wiwin, S. D. Y., Runik, D. P. and Adi, S. (2015). Growth and physiological characteristics of soybean genotypes (*Glycine max* L.) toward salinity stress. *Agrivita* (36)3

Okorie, N., Eze. N, and Anya, C. (2017). Environmental impact of salt mining in Nigeria: A case study of Yala Local Government Area *Monitoring and Assessment*, 189(6), 278.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982) Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. American Society of Agronomy. In Soil Science Society of America, Vol. 1159.

Rani, B., and Sharma, V.K. (2015). Standardization of methodology for obtaining the desired salt stress environment for salinity effect observation in rice seedlings.

Shrivastava, P., and Kumar, R. (2019). Soil Salinity: A major constraint to crop production. *Journal of Soil Science and Plant Nutrition*, 19(3), 547-558.

Smurutishree S., Bhagawati B. and Nitesh. (2016). Salinity tolerance in wheat. *Marumegh*:3(1).

Soha, E. K. (2020). The effect of salt stress on some physiological and biochemical composition of some crops. *Plant Archives* (20), 3573-3585.

Trough, E. (1930). Determination of Readily Available Phosphorus in Soils. *Journal of the American Society of Agronomy, 22(8): 874-882.*

Udo, E.J., Ibia, T.O., Ogunwale, J.A., Ano, A.A., and Esu, I.E. (2009). Manual of Soil, Plant and Water Analysis. Ist Ed. Sibon Books Limited, Lagos. 102pp.

Upadhyay, P., Shrivastava, M. K., Sharma, S., Ramakrishnan, R. S., Nagre, S. P., and Mohare, S. (2022). Evaluation of Growth, Physiological, and Quality Parameters on Seed Yield of Soybean [Glycine max (L.) Merrill]. *International Journal of Plant & Soil Science*, 34(18), 39–44. https://doi.org/10.9734/ijpss/2022/v34i1831050.

USDA. (1960). Soil classification, a comprehensive system 7th approximation. United States Department of Agriculture Washington, 4625Pp