The Effect of Sodium Chloride Salinity Stress on the Growth and Yield of Two Varieties of Soybean Plant (*Glycine max* L.)

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ABSTRACT

Soybean (*Glycine max* L.) is a protein-rich food commodity used in various processed products whose availability in Indonesia is still low. The main factors causing its low production were conversion and climate change. Efforts to overcome this condition were to use superior varieties such as Grobogan and Wilis and the utilization of marginal land such as tidal land. However, high soil salinity in coastal areas can inhibit soybean growth. This study aimed to determine the effect of salinity stress on the growth and yield of Grobogan and Wilis soybean varieties and the tolerant dose of NaCl salt for soybean. The study was conducted at the Experimental Garden of the Faculty of Agriculture, Andalas University, Indonesia, from May to August 2024. The study used a factorial completely randomized design (CRD) with two factors: soybean varieties (Grobogan and Wilis) and NaCl salinity levels (0 g/l, 2.5 g/l, 5 g/l, and 7.5 g/l). The data obtained were analyzed statistically using the F test at a significance level of 5%, and if there was a significant effect, it was then continued with Duncan's New Multiple Range Test (DNMRT) with a level of 5%. The results showed that the interaction between varieties and salinity stress did not significantly affect the studied parameters. The Grobogan and Wilis varieties gave similar responses. However, salinity stress affected all parameters except the number of seeds per pod. The salinity dose that can still be tolerated was 2.5 g/l.

Keywords: Grobogan, Wilis, salinity, soybeans variety.

INTRODUCTION

Soybeans (*Glycine max* L.) are a protein-rich food source used in various processed products such as milk, tempeh (an Indonesian dish made by deep-frying fermented soybeans), tofu, and soy sauce. Soybeans have a composition of around 40% protein, 20% oil, and 35% carbohydrates in dry weight. So that due to its many benefits, the need for soybeans in Indonesia is very high, and production needs to be increased. A report from the USDA (2023) in Rahmanulloh (2023) shown that in 2022-2023, soybean consumption is estimated to reach 2.86 million tons, while production is only 300 thousand tons, which makes Indonesia dependent on imports. The BPS-Statistics Indonesia (2024) noted that Indonesia's soybean imports in 2022 reached 2.32 million tons, and in 2023, reached 2.27 million tons; although it decreased, the import value remained high due to insufficient production.

Soybean production in Indonesia still needs to be improved due to the reduction in agricultural land. This reduction is due to land conversion into settlements and climate change. One solution to increase soybean production is the efficient use of and development of superior varieties, such as Grobogan and Wilis, which resist difficult environmental conditions. The Grobogan variety has an average yield of 2.77 tons/ha, while Wilis is 1.6 tons/ha (Fattah et al., 2021). Extensification of agricultural land by utilizing marginal land, such as tidal land, can also support production, especially in West Sumatra, which has a significant coastal area. West Sumatra has a coastal area of around 186,500 km^2, or 4 times the existing land area, with a coastline of 2,420.4 km (Aldian et al., 2022). However, the land in the West Sumatera is saline due to exposure

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to seawater. Salinity is the dissolved salt level in water and soil and is a limiting factor in soybean cultivation, especially in coastal areas. High salinity can hurt soybean growth and yields, even causing crop failure. Salinity is caused by the presence of NaCl. Although NaCl is essential for plant growth, excess can disrupt growth patterns. Salinity stress inhibits vegetative growth by reducing root length, plant height, leaf area, and biomass and reducing the number of pods and seed yields (Sinaga et al., 2023; Yunita et al., 2023). Legume plants generally tolerate salinity stress due to their ability to accumulate Potassium (K) and inhibit the movement of Na from the roots to the upper part of the plant. Soybean is classified as salinity-sensitive plant with a tolerance threshold of 2-5 dS/m (1.28 g/l - 3.2 g/l) (Taufiq et al., 2020).

Furthermore, Otie et al. (2021) found that plant height, number of leaves, and leaf area of soybean plants will grow at a salinity of 1000 - 5000 ppm (1 g/l - 5 g/l). However, very high salinity levels can be a challenge for this plant. Based on research by Wang et al. (2001), soybean germination and growth have decreased at a soil salinity of 11 dS/m (7 g/l of water). In his research, Amirjani in Mardhiana (2019) noted a decrease in plant height of 47% and fresh plant weight of 54% at a salinity stress of 5844 ppm (5.8 g/l of water). This study aimed to see the effect of salin stress on the growth and yield of Grobogan and Wilis soybean varieties on salinity stress and to determine the dose of NaCl salt that is tolerat by soybean plants.

MATERIAL AND METHODS

This research was conducted at the Experimental Garden of the Faculty of Agriculture, Andalas University, Padang, Indonesia, in an experiment in which salt stress was induced by administering saline solutions with NaCl in different concentrations. The Grobogan and Wilis variety seeds were sown in polybags (volume 8 kg) in Ultisol soil. Urea fertilizer, TSP, KCl, cow manure, dolomite lime, Regent 50SC Red® insecticide with active ingredient fipronil 50 g/l, and Furadan® were applied.

The study used a Factorial Completely Randomized Design (CRD) with two factors. The first factor was the variety, namely soybean varieties Grobogan (A1) and Wilis (A2). The second factor was NaCl salt salinity stress consisting of four levels, namely: NaCl 0 g/l water (B0); NaCl 2.5 g/l water (B1); NaCl 5 g/l water (B2); NaCl 7.5 g/l water (B3). Eight treatment combinations were repeated 3 times in this experiment, so there were 24 experimental units.

The treatment was carried out by weighing table salt (coarse) according to the treatment and then dissolved in 1 liter of water. The NaCl salt solution was given twice a week (every 2 weeks is one period), starting from 2 weeks after planting (WAP) until harvest, and it was given to each polybag in as much as 200 ml.

The observation data were analyzed statistically using the F test at the 5% level. If the calculated F of the treatment was greater than the F table (the treatment had a significant effect), then it was continued with the Duncan New Multiple Range Test (DNMRT) at the α level of 5%.

RESULTS AND DISCUSSION

Number of Root Nodules

The number of root nodules parameter indicates how many root nodules in plants function actively in the nitrogen fixation process. Data from the variance analysis using the F test can be seen in Table 1. Table 1 shows that the active root nodules of two soybean varieties are not influenced significantly by salt stress, meaning both varieties have a similar tolerance level to the given salinity conditions. In the single factor, salinity at 0 g/l and 2.5 g/l had the same effect but significantly differed in the treatments of 5 g/l and 7.5 g/l. This data showed that the higher the salinity, the fewer active root nodules formed.

Table 1. Active root nodules of soybean varieties Grobogan and Wilis under various NaCl salt doses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	9.33	8.33	6,67	6,33	7.65
Wilis	10.33	9.00	7,00	7.00	8.33
Average	9.83A	8.67A	6.86B	6.60B	
CV	15.73%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

Increasing salinity has reduced aerobic respiration so that symbiosis, initiation, and development of root nodules are disrupted due to damage to root hairs (Gupta and Das, 2019). Root nodule formation and N fixation decreased at 27 mM (1.6 g/l) NaCl salinity. High salinity has caused osmotic stress in plants, reducing water absorption and causing cell dehydration (Ondrasek et al., 2022). The most problematic environment for rhizobium to form is marginal land with low rainfall, extreme temperatures, acidic soil with low nutrient status, and poor water retention capacity. In addition, the formation of root nodules can be influenced by several factors such as temperature, light intensity, soil pH, and nutrient content in the soil (Anugrahtamaet al., 2020).

The variety factor did not affect the parameter of the number of active root nodules. The average Grobogan and Wilis varieties did not differ significantly because environmental influences formed root nodules. Root nodules are colonies of Rhizobium sp. According to Manasikana et al. (2019), factors influencing the development and activity of rhizobium in the soil were humidity, aeration, temperature, organic matter content, soil acidity, inorganic nutrient supply, soil type, and percentage of sand and clay.

Root Length

Root nodules influenced root length because root nodules have helped supply nitrogen and produce auxin hormones by Rhizobium bacteria, which support root growth. Active root nodules increase the concentration of auxin hormones, which encourage longer root growth. The data from the variance analysis using the F test can be seen in Table 2. Table 2 shows that the salinity factor at 0 g/l and 2.5 g/l was not significantly different; the 2.5 g/l treatment had a better effect on root structure. In line with Silva et al. (2021), lower salt stress (50 Na^+ or 2.9 g/l) increased the root epidermis's and endodermis's thickness.

Table 2. Root length of soybean varieties Grobogan and Wilis under various NaCl salt doses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	49.50	48.53	44,.00	43.00	46.25
Wilis	52.00	50.67	45.33	44.00	48.00
Average	50.75A	49.60A	44.66B	43.50B	
CV	7.18%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

The 5 g/l and 7.5 g/l treatments have suppressed the root length parameters. This treatment was thought to cause reduced cell division in the roots. The inhibition of root growth was caused by the absorbed Na compound accumulating in the roots, thus disrupting the absorption of nutrients (Yunita et al, 2020). As a result, the plant growth process was disrupted.

The variety factor showed no effect of variety on root length parameters, it is suspected that the environment in the form of growing media is more dominant in influencing root length parameters even though the varieties planted are different. The varieties are limited by the influence of the abiotic and biotic environment.

Plant Height

Plant height is influenced by root length because longer roots allow for the absorption of more nutrients, such as N, P, and K. These nutrients support photosynthesis and stem and leaf growth, contributing to increased plant height. Data from the variance analysis using the F test can be seen in Table 3.

Table 3. Height of soybean plants of Grobogan and Wilis varieties under various NaCl salt doses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	43.20	42.50	39.09	36.27	40.26
Wilis	46.43	44.39	37.42	36.97	41.30
Average	44.82A	43.45A	38.25B	36.62B	
CV	9.10%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

Duncan's further test showed that the height of soybean plants at 0 g/l salinity stress was not significantly different from 2.5 g/l, which indicates that 2.5 g/l salinity is still tolerant. Soybeans can synthesize secondary metabolites to reduce osmotic stress, in line with Munns and Tester (2008), which stated that plants from the Fabaceae family, including soybeans, can reduce osmotic stress by synthesizing peroxidase compounds. In contrast, salinity treatments of 5 g/l and 7 g/l showed significant differences with treatments of 0 g/l and 2.5 g/l, indicating that soybean growth was affected by NaCl levels. The higher the salinity dose, the greater the impact on soybean growth because osmotic stress inhibits water absorption and affects cell division and enlargement (Anugrahtama et al., 2020).

Table 3 shows that neither variety provided a significant difference in plant height. Uniform growth might influenced by the same environmental conditions, not by the genotype of the variety. Genes and genotype characteristics play a lesser role, while the growing environment has a greater influence on plant height. Environmental factors were more dominant than genetic factors in low to medium characters. The graph of plant height growth from 2-5 periods after planting is shown in Figure 1. Figure 1 shows that the height growth of both soybean varieties under salinity stress follows almost the same pattern. At salinity of 0 g/l and 2.5 g/l, plant growth was similar from 2 to 5 WAP, while salinity of 5 g/l and 7.5 g/l showed slower growth, especially at 4-5 WAP. This data shows that the longer the plant was exposed to salinity, the greater the negative effect on height growth.

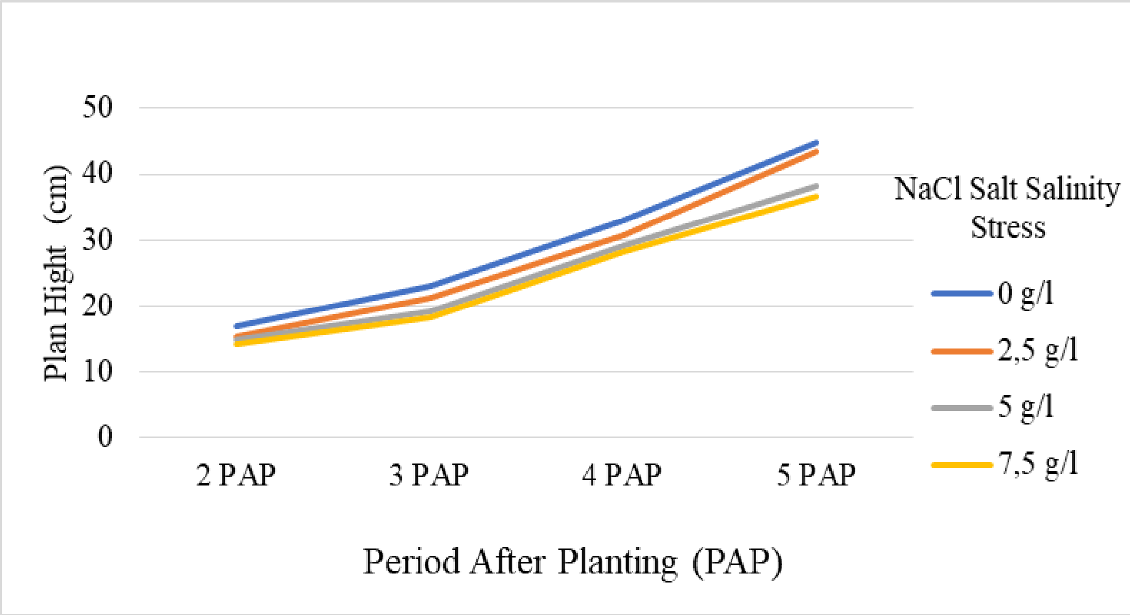

Figure 1. The average of plant height rate of two soybean varieties under various NaCl salt salinity stresses at 2-5 period after planting

Number of Leaves

The growth of leaves was in line with the height of the plant because the increase in height provided more space for new leaves to develop at the top and lateral parts of the stem. The data from the variance analysis using the F test can be seen in Table 4. Table 4 shows further tests on the number of leaves, underscoring the importance of understanding the impact of salinity stress on leaf growth. The data reveals that salinity stress of 0 g/l significantly differed from 5 g/l and 7.5 g/l but not from 2.5 g/l. At 2.5 g/l, the plants have not shown stress because soybeans are still tolerant to that concentration. This finding was in line with research by Fuskhah et al. (2014), which found that NaCl concentrations of 2 g/l to 4 g/l still support plant growth without significant effects.

The 5 g/l and 7.5 g/l treatments showed no difference, but both significantly differed from 0 g/l and 2.5 g/l. This data proved that excess NaCl inhibits soybean growth, including decreased leaves. Otie et al. (2021) found that high salinity of 86.30 mM (5 g/l) reduced plant height and number of leaves. High salinity inhibits cell elongation and division and affects the function of hormones such as auxin and cytokinin. In addition, excess NaCl causes ion imbalance, especially reducing the absorption of K+ ions, which are important for osmosis and photosynthesis.

Table 4 shows that the variety has no significant effect on the number of leaves. The average number of leaves in the Grobogan and Wilis varieties is almost the same, indicating that genetic factors do not affect the growth of the number of leaves. This finding, in line with the report of Kao et al. in Kirova and Kocheva (2021), which states that under stress conditions, plants are more influenced by the environment than genetic factors, highlights the complex interplay of genetic and environmental factors in leaf growth. The growth rate of the number of leaves can be seen in Figure 2.

Table 4. Height of soybean plants of Grobogan and Wilis varieties under various NaCl salt doses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	10.67	9.83	8.41	7.67	9.15
Wilis	11.33	10.58	7.75	7.00	9.16
Average	11.00A	10.21A	8.08B	7.33B	
CV	8.42%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

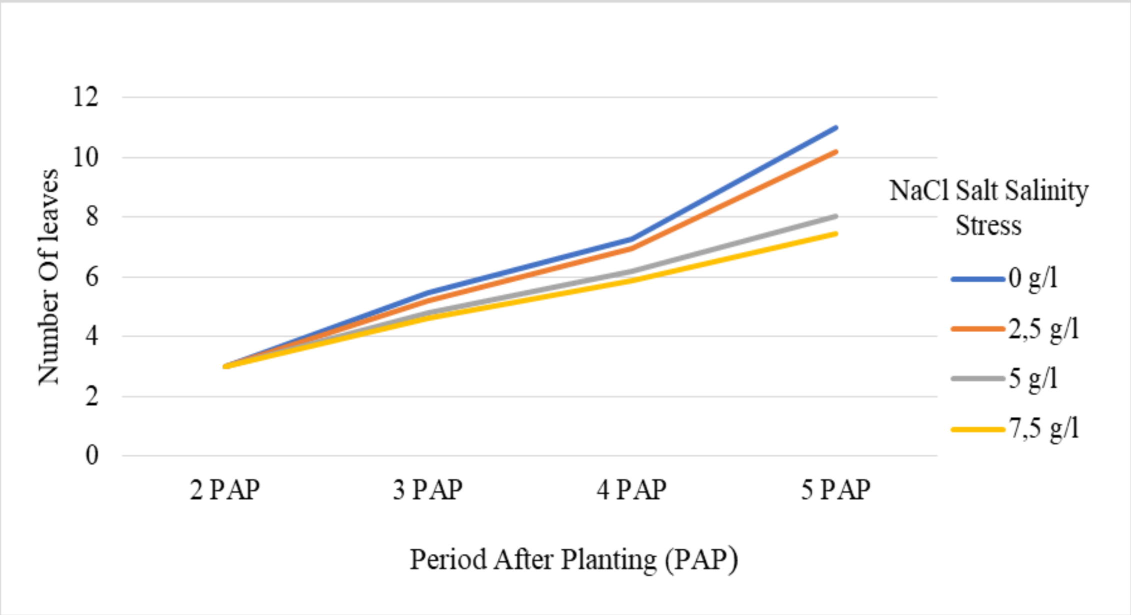

Figure 2. The average growth rate of the number of leaves of two soybean varieties under various NaCl salt salinity stresses at the age of 2-5 period after planting

Figure 2 shows that the growth of the number of leaves of the two soybean varieties under various salinity stresses follows a similar pattern. At stresses of 0 g/l and 2.5 g/l, leaf growth was almost the same from 2 to 5 WAP, while stresses of 5 g/l and 7.5 g/l showed slower growth, especially at 4-5 WAP. This data shows that as the plant's age increases, salt stress's effects become more visible. In accordance with Kamran et al. (2019), the decrease in leaf growth rate is an adaptation to salt stress that inhibits water absorption and limits transpiration.

Leaf Area

Observations Plant height influences leaf area because taller plants have more opportunities to develop larger leaves, especially at the top, where sunlight is more intense to be received. This condition allows plants to maximize light absorption, making the leaf area more prominent. The data from the variance analysis using the F test can be seen in Table 5.

Table 5 highlights the significant impact of salinity stress on leaf area. The treatments of 5 g/l and 7.5 g/l showed significant differences, indicating a negative impact of salinity on leaf area. As salinity increases, it reduces water loss through transpiration, causing physiological drought, reducing relative water content and leaf turgor pressure, which inhibits cell expansion. Salinity also affects leaf morphology, making them smaller with smaller stomata, increasing succulents, and thickening of the cuticle.

Table 5. Height of soybean plants of Grobogan and Wilis varieties under various NaCl salt doses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	875.67	837.50	701.38	610.61	756.29
Wilis	914.92	900.30	762.13	704.00	820.34
Average	895.30A	868.90A	731.70B	657.30B	
CV	9.52%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

The variety factor did not affect leaf area, possibly because the Wilis and Grobogan varieties have genetic similarities. Research by Mas'ula et al. (2018) also showed that differences in varieties do not significantly affect leaf area because genetic similarities affect the number and area of leaves.

Number of Pods per Plant

Growth variables greatly influenced the number of pods per plant. Taller plants tend to have more leaves and stems that support pod development. The more leaves, the greater the photosynthetic capacity, which can increase the number of pods. The data from the variance analysis using the F test can be seen in Table 6. Table 6 shows that the salinity of 0 g/l and 2.5 g/l was not significantly different, but there was a significant difference at 5 g/l and 7.5 g/l. Water shortages due to salinity impact the pod formation. Hasanuzzaman et al. (2022) noted that salinity stress has changed plants' morphology, physiology, and biochemistry, disrupting reproduction and yields. Hassan et al. (2024) found that the highest number of pods per plant occurred at a salinity of 1 ds/m (0.64 g/l) compared to 5 ds/m (3.2 g/l). The number of pods, seeds per pod, and weight of 100 seeds play an important role in bean yield. The total number of pods was susceptible to environmental stress because this component was formed earlier in the generative phase, making it more susceptible to stress.

Table 6. Number of pods per soybean plant of Grobogan and Wilis varieties under various NaCl salinity stresses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	25.75	24.67	20.83	16.00	21.81
Wilis	31.91	25.58	18.12	16.00	22.90
Average	28.83A	25.12A	19.29B	16.00B	
CV	19.72%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

The variety factor did not significantly affect the number of pods per plant. Genetic factors influence the number of filled pods in soybeans. However, environmental factors also influence it, especially from flowering to seed filling (Sjamsijah et al., 2018). In addition, the number of pods was also influenced by the number of flowers that become fruit and the photosynthesis process during the vegetative phase. The rate of photosynthesis and the supply of assimilation results play a role in determining the number of pods (Umarie and Holil, 2017).

Pod Weight per Plant

Pod weight per plant is related to the number of pods produced by the plant because the more pods produced, the greater the pod weight per plant. Data from the variance analysis using the F test can be seen in Table 7.

Table 7. Weight of pods per soybean plant of Grobogan and Wilis varieties under various NaCl salinity stresses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	12.16	11.67	8.25	7.16	9.81
Wilis	13.58	11.67	7.87	7.12	10.06
Average	12.88A	11.67A	8.04B	7.15B	
CV	24.80%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

In Table 7, the salinity factor shows that the 0 g/l and 2.5 g/l treatments are not significantly different, but the 5 g/l and 7.5 g/l treatments significantly reduce the pod weight per soybean plant. Research by Suryaman et al. (2021) indicated that salinity stress can reduce pod weight by up to 53% in mung beans. Filipović et al. (2020) reported that faba bean pod weight decreased significantly due to high salinity, with more than a third of the total pod weight lost due to highly saline irrigation water (100 mM or 5.8 g/l). Mardhiana et al. (2019) also stated that applying NaCl during the generative phase causes stomatal closure, reduces CO_2 assimilation, and inhibits photosynthesis, negatively impacting fresh fruit weight.

The variety treatment factor did not significantly affect the two varieties tested. According to Smith and Doe (2022), the number of pods formed varies depending on the variety, soil fertility, and cultivation techniques. In this study, environmental factors have a greater influence.

Number of Seeds per Pod

The analysis of variance showed no significant interaction between varieties and NaCl salt salinity stress on the number of seeds per pod in soybeans. Single factors also did not show a significant effect on this parameter. Data from the variance analysis using the F test can be seen in Table 8.

Table 8. Number of seeds per pod of Grobogan and Wilis soybean varieties under various NaCl salinity stresses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	2.39	2.30	2.23	2.20	2.28
Wilis	2.42	2.38	2.32	2.26	2.34
Average	2.40	2.34	2.27	2.23	
CV	41%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

Salinity stress did not affect seed formation in soybean pods, possibly because the number of seeds per pod was relatively consistent, such as 2-3 seeds (Otie et al., 2021). In stressed conditions, soybeans can adapt by allocating resources for seed formation so that the number of seeds per pod remains insignificant. However, other parameters, such as the number of pods (Table 6) and seed weight (Table 10), show significant differences due to varying seed sizes.

The variety factor in Table 8 shows no significant difference between the varieties tested. Although the varieties differ, the same environmental factors also affect the number of seeds per pod. Mulatsih (2023) stated that environmental factors influence plant growth and production, including nutritional needs and climate. Meage et al. (2023) added that sucrose formation and seed filling are inhibited if light is insufficient. In conditions of high rainfall and cloud cover, plants lack light, which hurts photosynthesis results.

The weight of 100 seeds

100 seed weight is influenced by pod weight because heavier pods tend to contain larger and well-developed seeds. The data from the variance analysis using the F test can be seen in Table 9. In Table 9, the salinity factor showed that the 0 g/l and 2.5 g/l treatments were not significantly different, while they were significantly different from the 5 g/l and 7.5 g/l treatments, which reduced the weight of 100 soybean seeds. Gul et al. (2022) reported a decrease in the number of pods and 100 seed weight at concentrations of 70 mM (4 g/l) and 140 mM (8.1 g/l) NaCl. Barus et al. (2022) also found a decrease in dry seed weight and 100-seed weight at a salinity of 2.34 dS/m (1.4 g/l), with the largest decrease at 3.51 dS/m (2.2 g/l), which reduced the 100-seed weight by 20%.

Table 9. Weight of 100 soybean seeds of Grobogan and Wilis varieties at various NaCl salinity stresses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	14.47	14.01	12.36	12.33	13.29
Wilis	14.30	14.08	12.14	11.77	13.07
Average	14.39A	14.05A	12.24B	12.11B	
CV	6.74%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

The variety factor did not significantly affect the 100-seed weight. Research by Patil et al. (2021) showed that despite genetic variation between varieties, the 100-seed weight did not consistently differ significantly. Uniform and stressed environments can affect the homogeneity of 100-seed weight between varieties, disguising genetic differences. Zhang et al. (2023) also reported that environmental influences were more dominant under stressed conditions than genetic factors.

Seed Weight per Plant

Seed weight per plant is influenced by 100-seed weight, which reflects the average size and quality of seeds. The weigher of 100 seeds indicates larger and heavier seeds, thus increasing the total seed weight per plant. The data for the variance analysis using the F test can be seen in Table 10. In Table 10, the salinity factor shows no significant difference between 0 g/l and 2.5 g/l but significantly differed in the 5 g/l and 7.5 g/l treatments, which reduced the seed weight per soybean plant. Hasanuzzaman et al. (2022) stated that salt stress reduces the number of pods and seed weight as Na^+ accumulation increases in leaves. Seed size is related to seed weight per plant, where salinity stress causes seeds to become smaller. Cao et al. (2018) also explained that soybean seed weight experienced a significant decrease in salinity stress conditions due to decreased photosynthesis, stunted growth, accumulation of Na^+ and Cl^- ions, and production of reactive oxygen species (ROS).

Table 10. Seed weight per plant of Grobogan and Wilis soybean varieties under various NaCl salinity stresses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	7.41	7.25	5.50	5.25	6.35
Wilis	8.00	7.67	5.83	4.00	6.37
Average	7.71A	7.46A	5.64B	4.75B	
CV	22.00%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

The variety factor did not have a significant effect, whereas the Grobogan and Wilis varieties had the same average seed weight. This data may be due to external factors, such as the environment, which influence seed weight more. Yusuf (2019) stated that the seed-filling period is critical in soybean growth. Environmental factors influence the results of seed weight per plant more than variety treatment. High temperatures can affect the rate of respiration and photosynthesis, where low photosynthesis interferes with the pod-filling phase and reduces yields.

Production per hectare is the total weight of seeds from all plants in one hectare. Increasing the weight of seeds per plant will also increase production per hectare as long as the number of plants per hectare remains the same or increases. The data from the variance analysis using the F test can be seen in Table 11. In Table 11, the salinity factor shows that the treatments of 0 g/l and 2.5 g/l are not significantly different. However, there was a significant difference in the treatments of 5 g/l and 7.5 g/l, which reduces production per hectare of soybean plants. Otie et al. (2021) noted a significant decrease in yield as salinity increased, which was related to a decrease in yield components (number of pods and seeds per plant) due to salt stress. Khan et al. (2019) reported that salinity stress can result in yield losses of up to 40% in soybeans, depending on the salinity level, which negatively impacts seed quality, quantity, and production.

Table 11. Production per hectare of soybean plants of Grobogan and Wilis varieties under various NaCl salt salinity stresses

Variety	NaCl Dose in Inducing Salinity Stress				Average
	0 g/l	2.5 g/l	5 g/l	7.5 g/l	
Grobogan	1.85	1.81	1.45	1.31	1.60
Wilis	2.00	1.91	1.37	1.00	1.57
Average	1.93A	1.86A	1.41B	1.19B	
CV	22.00%				

Note: The numbers in the rows followed by the same capital letters are not significantly different according to the DNMRT test at the 5% level.

The variety factor did not show significant differences in production per hectare, with the Grobogan variety producing an average of 1.6 tons/ha and the Wilis variety 1.57 tons/ha. Both did not achieve the production target according to the variety description, possibly due to low nutrient availability. Nutrients such as nitrogen, phosphorus, and potassium are essential for plant growth. Soil analysis showed that N, P, and K availability was relatively low even though fertilization had been carried out. Due to salinity stress, the presence of other excessive nutrients, such as Na^+ and Cl^-, can interfere with the absorption of N, P, and K, reducing growth efficiency. High concentrations of Na^+ and Cl^- can cause toxicity to intolerant plants, making it difficult to absorb the necessary nutrients.

CONCLUSIONS

The results of the study showed that, NaCl treatment on soybean plants can inhibit plant growth. This can be seen from all parameters that indicate NaCl treatment inhibits growth except for the parameter of the number of seeds per pod, with the provision of NaCl treatment showing higher results. Research on salinity stress in soybeans must be continued with other varieties to obtain more information about varieties resistant to salinity. Further complementary studies in coastal areas with natural salinity variations are needed to confirm these findings.

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