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Effect of Salinity Stress on Plant Growth and Yield of Two Varieties of Soybean (*Glycine max* L.) in Saline Soil

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ABSTRACT

This study aims to determine the response of soybean varieties tolerant to salinity stress and the impact of NaCl on the growth and yield of soybean. The study was completely designed randomly with two factors, repeated four times. First factor was NaCl concentration consisting of four levels (0; 2.5; 5; and 7.5 g/l), and second factor was soybean varieties (Wilis and Anjasmoro). The data obtained were analyzed using ANOVA followed by HSD test of 5%. Observation variables included plant height, number of leaves, number of productive branches, number of pods per plant, and weight of 100 seeds. Results showed that both NaCl concentration and soybean variety had no significant effect on plant height, number of pods, and weight of 100 seeds. The interaction of NaCl concentration and variety significantly affected the number of leaves and the number of productive branches. Results showed that Anjasmoro variety with no NaCl (0 g/l) treatment revealed the highest number of leaves, namely 5.50 strands. Whiles, the combination of 7.5 g/l NaCl and Wilis variety produced the highest productive branches, namely 4.25 branches. The results of this study are to provide information on the use of saline land in soybean plants by knowing the resistance of soybean varieties to salinity.

1. INTRODUCTION

Soybeans (*Glycine max* L.) are a common source of vegetable protein and are the third most important food for Indonesian people after rice and corn. Soybeans are a common food crop in Indonesia. However, soybeans are not native to Indonesia. Soybeans are believed to originate from northern China (Manshukuo region), where they were first cultivated in the 11th century AD, and in Indonesia itself soybeans were cultivated as food and as green fertilizer in the 17th century (Atman, 2014). Soybeans are generally used as the main raw material for making tempeh and tofu.

Domestic soybean raw material needs are 3.1 million tons of dry beans or around 11.89 kg per person. The use of soybean products is not in accordance with Indonesia's soybean production capacity. This demand can only be met by around 30% of the 538,000 tons of dry seed soybeans produced by domestic farmers (Badan Pusat Statistik, 2017). To overcome the shortage of soybean production, methods have been implemented to utilize marginal land, such as acidic or saline soil, and convert this marginal land into productive land for planting soybeans (Sinuraya *et al*., 2016).

The problem is that every year the land suitable for agriculture is decreasing from year to year due to the conversion of agricultural land to non-agricultural land in Indonesia. The alternative is to utilize land that is not optimal for agricultural land. Saline land is underutilized because its productivity is low and it is not suitable for agriculture. According to Masganti *et al*. (2022), the area of saline land in Indonesia reaches 0.4 million hectares. This is an initiative to utilize saline soil containing NaCl (salt) as agricultural land. The development of soybean cultivation on saline soil faces obstacles due to the lack of officially approved salinity-tolerant varieties.

Salinity is a threat to soybean cultivation and can cause stunted plant growth and changes in plant structure such as reduced leaf size, denser stomata, and premature root lignification. Soil and nutrient management is one of the keys to success in saline soils. Proper soil and nutrient management can minimize these disturbances (Yulianto *et al*., 2017). Increased salinity in soybean plants reduces plant height, total biomass, and yield, leaves quickly experience premature shedding (senescence) (Ismail *et al*., 2018). Salt stress can increase the production of reactive oxygen species (ROS), which can disrupt cell membrane stability, damage key proteins and enzymes in cell metabolism, and damage DNA. Salinity can be defined as a soil condition with EC> 4 dS/m (equivalent to 40 mM NaCl), osmolality 0.2 MPa, and exchangeable sodium fraction (ESP) <15. Salinity can occur in dry climates and coastal tidal wetlands. As a result of soil degradation on suboptimal land, the area of saline land is increasing. Excessive fertilization, inadequate irrigation systems, and climate change are some of the factors causing salt damage (Putri, 2016).

The Wilis soybean variety is one of the superior soybean varieties introduced on July 21, 1983, SK Mektan: TP240/519/Kpts/7/1983 and is widely cultivated in the Malang area. The advantages of this variety are that it is resistant to blight and resistant to leaf rust and viruses. The potential yield of the Willis soybean variety is 1.6 tons/ha. The Anjasmoro variety is a soybean variety that is often cultivated in Indonesia because it has several advantages in the form of tolerance to water-saturated soil conditions, does not fall easily, and pods do not break easily. The potential harvest for the Anjasmoro soybean variety is 2.25 tons/hectare. The Wilis and Anjasmoro varieties can witDAPand high salinity in coastal areas because these varieties are tolerant to salinity (Balitkabi, 2016). Variety selection is also important to support the productivity of soybeans planted on saline soil. It is hoped that by using several high-quality varieties, production problems such as acidity, nutrient imbalance, drought and salinity can be more easily overcome.

Research on several soybean varieties at different levels of NaCl concentration as an alternative to different levels of land salinity stress is expected to be a solution to overcome the problems of soybean cultivation on suboptimal land, especially saline land. The soybeans used in this study were the Wilis and Anjasmoro varieties. The purpose of this study was to determine the response of soybean varieties that are tolerant to salinity stress and to provide information on the impact of NaCl on the growth and yield of soybean plants.

2. MATERIALS AND METHODS

2.1. Research Time and Location

This research was carried out in March 2024 - June 2024 at the Agro-climate Station Land, Faculty of Agriculture, East Java "Veteran" National Development University, Surabaya City, with coordinates 7°20'07" S and 112°47'38" E, and an altitude of 4 meters above sea level, temperature ranges from 25–33°C and average rainfall is 276 mm/month. The materials used in this study were soybean seeds of the Wilis and Anjasmoro variety, salt (NaCl), polybags, saline soil, and Android 72 EC insecticide.

2.2. Research Design and Data Analysis

This experimental design was arranged using CRD (Completely Randomized Design) with two treatments, NaCl concentration as the first factor and variety as the second factor. NaCl concentration (S) consisted of 4 levels, namely (0; 2.5; 5; and 7.5 g/l) and variety (V) consisted of Wilis (V1) and Anjasmoro (V2). There were 8 treatment combinations, each treatment combination was repeated 4 times, so that 32 experimental units were obtained (Figure 1). The observation data were analyzed using the analysis of variance (ANOVA), if it shows a significant effect; it will be continued with the HSD (Honestly Significant Difference) test at a level of 5%.

2.4.2. Seed Preparation and Planting

The soybean seeds were Wilis and Anjasmoro varieties. Before hsing, the seeds were soaked in water for 30 min. The soaking aims to select seeds that are suitable for planting and to awaken the dormancy period of the soybean seeds. Only healthy soybean seeds that are free from deformation, clean from dirt, free from pests and diseases were selected. Planting was performed by making hole 3-4 cm deep and inserting 2 soybean seeds per plastic bag, and covering lightly with planting media.

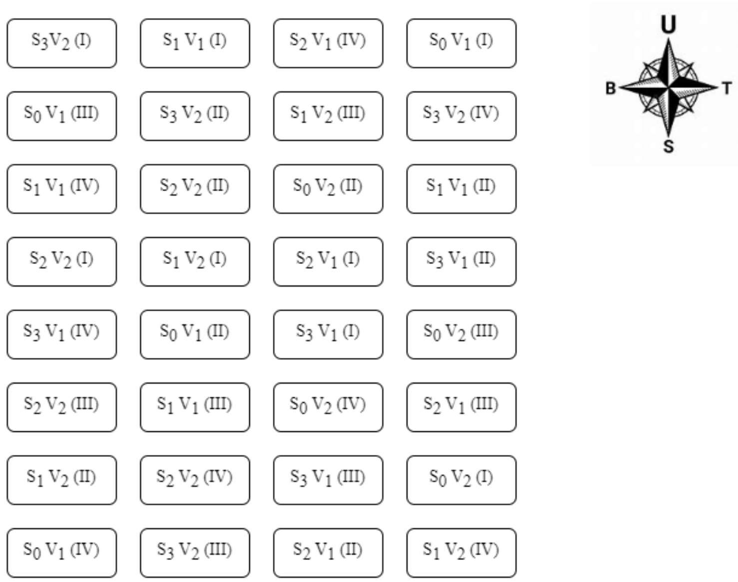

Figure 1. Experimental layout (S = Saline soil + NaCl concentration; V = variety; (I) – (IV) = replication)

2.4.4. Maintenance

Watering of soybean plants was done every day in the afternoon, from the beginning of planting until near harvest. Weeding of soybean plants was done mechanically by pulling out weeds growing in the polybag. Fertilization was done 2 times at 7 days after planting (DAP) and 35 DAP. The basic fertilizers included inorganic fertilizers Urea, TSP, and KCl. Fertilization was done by digging holes in the polybag around the soybean plant. Spraying insecticide Android 72 EC was applied to control leaf beetles and soybean pod borers.

2.4.5. Application of NaCl

NaCl was applied 1 time when the soybean plants were 10 DAP old. NaCl application was done by dissolving in one liter of water, and sprinkling all over the soil of the research polybag until wet. The NaCl concentration was given according to the treatment level, namely 0, 2.5, 5.0, and 7.5 g/L.

2.4.6. Harvesting

The criteria for harvesting soybeans for harvesting are fully filled pods, dry and brown pods, yellow leaves and easy to fall off. Harvesting of soybean plants was done by cutting the stem of the plant and picking the pods from the plant. Harvesting of soybean plants was done when the soybeans were 85 DAP.

2.4.7. Observation Parameters

In this study, the supporting parameters for soybean growth and yield included: plant height, number of leaves, number of productive branches, age of flower emergence, number of pods per plant, and weight of 100 soybean seeds.

3. RESULTS AND DISCUSSION

3.1. Plant Height

The results of the ANOVA analysis showed that there was no significant interaction between the NaCl concentration and variety treatments on the soybean plant height parameter. Likewise, the single factor NaCl and variety did not show a significant effect on the soybean plant height during the observation. The average value of soybean plant height in the combination treatment of NaCl concentration with varieties is presented in Table 2. The application of NaCl concentrations of 0 g/L to 7.5 g/L and the Wilis and Anjasmoro varieties did not give significantly different effect

Table 2. Average soybean plant height (cm) under NaCl concentration and variety treatments

Treatment	DAP							
	14	21	28	35	42	49	56	63
NaCl								
S0 (0 g/L)	13.50	19.25	25.50	32.75	39.12	45.25	47.37	48.75
S1 (2.5 g/L)	13.00	17.12	22.25	28.50	36.00	40.37	41.12	41.50
S2 (5 g/L)	12.75	16.62	21.87	28.87	34.25	38.00	38.87	39.25
S3 (7.5 g/L)	13.12	18.00	24.37	31.12	38.12	42.00	43.75	44.37
HSD 5%	ns	ns	ns	ns	ns	ns	ns	ns
Variety								
V1 (Wilis)	12.62	17.12	22.62	29.12	35.43	40.12	40.68	40.87
V2 (Anjasmoro)	13.56	18.37	24.37	31.50	38.31	42.68	44.87	46.06
HSD 5%	ns	ns	ns	ns	ns	ns	ns	ns

Note: ns = not significant.

on the parameters of soybean plant height. The NaCl concentration of 0 g/L had the highest plant height at each observation age, however, these results were not significantly different from other NaCl concentrations, while the Anjasmoro variety gave the highest plant height at each observation age, however, these results were also not significantly different from other varieties. Observations of plant height under NaCl salt stress conditions at all concentrations showed results that were not significantly different from the control. This is because both soybean varieties have the same tolerance and level of adaptation to NaCl treatment which has entered the saline category in these parameters. Plant height is a plant growth parameter that is observed as a parameter to determine the effect of the environment or the effect of treatment on plants (Khan *et al*., 2021). Research conducted by Ester & Wicaksono (2019) on pakchoy with three varieties (Flamingo, Green Pakchoy, and White Pakchoy) also did not show a significantly different response in plant height from 7 to 35 DAP. The decrease in plant height caused by osmotic stress can make it difficult for plants to absorb water, and the effect of excessive Na and Cl ions due to the addition of NaCl also results in inhibition of cell division and hypertrophy (Romadloni & Wicaksono, 2018).

3.2. Number of Leaves

The results of the ANOVA analysis on the observation parameters of the number of leaves in a unit of leaf blade showed a significant interaction between NaCl concentration and variety at the observation age of 28 DAP of soybean plants. The number of soybean leaves in the combination of NaCl concentration and variety after being tested with 5% HSD is presented in Table 3. The interaction of NaCl concentration and variety provides a response to the research variable of the number of leaves at 28 DAP. Based on the research, the results of the highest number of leaves with 5.50 were found in the interaction of NaCl 0 g/L and the Anjasmoro variety (S0V1), while the lowest number of leaves were found in the interaction of NaCl 0 g/L and the Wilis variety (S0V1) and S2V1 (NaCl 5 g/l and the Wilis variety) with 3.50 strands. This study shows that it is possible that at the age of 28 DAP or with a combination of these treatments, plants can still accumulate high NaCl salts so that the leaves are still able to grow normally and have not fallen off due to necrosis. This is in line with Yunita *et al*. (2018), who stated that the critical period is marked by the onset of necrotic damage to the leaves.

Table 3. Average number of soybean leaves under combined NaCl concentration and variety treatments at 28 DAP

NaCl Concentration	Variety	
	V1 (Wilis)	V2 (Anjasmoro)
S0 (0 g/l)	3.50 a	5.50 b
S1 (2.5 g/l)	4.50 ab	4.00 a
S2 (5 g/l)	3.50 a	4.75 ab
S3 (7.5 g/l)	4.75 ab	4.00 a
HSD 5%	1.50	

Note: Numbers followed by the same letter indicate a significant difference based on the LSD 5% test.

Leaves are vegetative organs in plants and are where photosynthesis takes place, so the number of leaves has a major influence on plant growth (Marian & Tuhuteru, 2019). Leaf necrosis is caused by poisoning due to the accumulation of $Na^{+}Cl^{-}$ in the leaves, and the accumulation of Na^{+} ions is the main cause of plant damage to salt stress. On the other hand, the Wilis variety is superior in terms of the number of leaves and tolerance to salinity stress. According to research by Purwaningrahayu & Taufiq (2017), in the Wilis variety which is sensitive to soil salinity shows a greater number of leaves so that the total leaf area is relatively higher at high salinity levels.

3.3. Number of Productive Branches

The number of Productive Branches is a branch of the plant that produces flowers and successfully forms pods. The results of the analysis of variance of the parameter number of productive branches showed a real interaction between NaCl concentration and variety at the age of 49 DAP. The average value of the number of productive branches of soybean plants in the combination of NaCl concentration and variety after being tested at 5% HSD is presented in Table 4. the interaction of NaCl concentration and variety giving response to the research variable of the number of productive branches. Based on the research results, it shows that the combination treatment that produces the highest productive branches is in the interaction of S3V1 (NaCl 7.5 g/l and Wilis variety) as many as 4.25 branches; S1V1 (NaCl 2.5 g/l and Wilis variety) as many as 3.75 branches with the same letter notation (b) which is significantly different from S0V1 (NaCl 0 g/l and Wilis variety) with the number of productive branches as many as 2.00 branches. In the results of the study, genetically, the Wilis variety soybean produces higher productive branches than the Anjasmoro variety and also shows resistance or tolerance to salinity stress, which can be juxtaposed with the high number of productive branches at the age of 49 HST. This statement is supported by Al-Ashkar *et al.* (2020), that some varieties are more tolerant to salinity and there are genetic differences in response to salinity, which can affect how many productive branches can be maintained by the plant. The formation of productive branches is influenced by competition between plants, especially in obtaining growth factors. The number of productive branches produces more pods per plant (Riyaningsih *et al*., 2018).

Table 4. Number of productive branches of soybean plants at 49 DAP under combined NaCl concentration and variety treatments

NaCl Concentration	Variety	
	V1 (Wilis)	V2 (Anjasmoro)
S0 (0 g/l)	2.00 a	3.50 ab
S1 (2.5 g/l)	3.75 b	2.50 ab
S2 (5 g/l)	3.25 ab	3.50 ab
S3 (7.5 g/l)	4.25 b	2.25 ab
HSD 5%	1.57	

Note: Numbers followed by the same letter within the same column and treatment indicate a significant difference based on the HSD 5% test.

3.4. Number of Pods

The results of the ANOVA analysis showed that there was no significant interaction between the NaCl concentration and variety treatments on the number of pods per plant parameter. Likewise, the single factor of NaCl concentration and variety did not show any significant effect on the number of pods per plant during the observation. The average value of the number of pods per soybean plant in the combination treatment of NaCl concentration with varieties is presented in Figure 2. The provision of NaCl concentrations of 0 g/l to 7.5 g/l and the Wilis and Anjasmoro varieties did not provide significantly different results on the number of pods per soybean plant. The NaCl concentration of 0 g/l showed the highest number of pods, namely 31.25, however, these results were not significantly different from other NaCl concentrations, while the Wilis variety gave the highest results in the number of pods, namely 29.37, however, these results were also not significantly different from the Anjasmoro variety. The results of the study on the number of pods per plant treated with different NaCl concentrations showed that each concentration was unable to produce the number of pods comparable to the control (0 g/L). This may be due to leaf damage due to NaCl salt at the pod formation stage, thus disrupting the photosynthesis process and reducing pod production. Soil salinity affects the growth, physiology, and production process of soybeans. High soil salinity can cause flowers to turn brown and fall off, thereby reducing the rate of pod formation (Nisak & Supriyadi, 2019). Hodiyah *et al.* (2021) conducted a similar

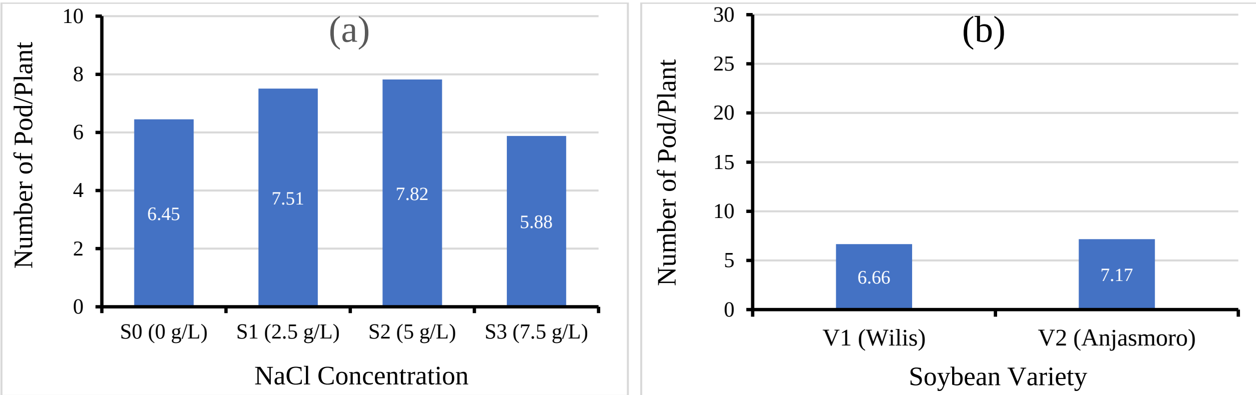

Figure 2. The average number of pods per plant due to single factor treatment: (a) NaCl concentration, and (b) Variety (both factors are not significant)

study, with three salinity levels, namely 0% NaCl, 0.5% NaCl, and 1% NaCl, also showed that the salinity level treatment had no significant effect on the number of pods per plant in soybeans. The effect of salinity on plants causes reduction on plant growth and production. High salt concentrations in the soil interfere with the process of filling soybean pods (Taufiq *et al*., 2016).

3.5. Weight of 100 Seeds

The results of the ANOVA analysis on the observation parameters of the weight of 100 seeds in grams showed that there was no significant interaction between NaCl concentration and varieties in soybean plants. Likewise, the single factors NaCl and varieties did not show a significant effect on the weight of 100 soybean seeds during the observation. The average value of soybean seed weight in the NaCl concentration and variety treatments is presented in Figure 3. The addition of NaCl concentrations of 0 g/l to 7.5 g/l and Wilis and Anjasmoro varieties did not provide significantly different results on the weight parameters of 100 soybean seeds. The NaCl concentration of 5 g/l showed the highest weight of 100 seeds, which was 7.82 grams, but this result was not significantly different from other NaCl concentrations, while the Anjasmoro variety showed the highest weight value, which was 7.17 grams, but this result was also not significantly different from the Wilis variety. This is due to the reduced level of NaCl salinity in the soil due to the washing process so that it does not have a significant effect on soybean yields. The weight of 100 seeds is a parameter that indicates the quality of the harvest produced by plants. The greater the weight value of 100 plant seeds, the higher the quality of the harvest. The 100 seed weight parameter also has a direct positive effect on yield. In other words, the greater the weight of 100 seeds, the greater the weight of seeds per plant. (Dwiputra *et al*., 2015). Similar

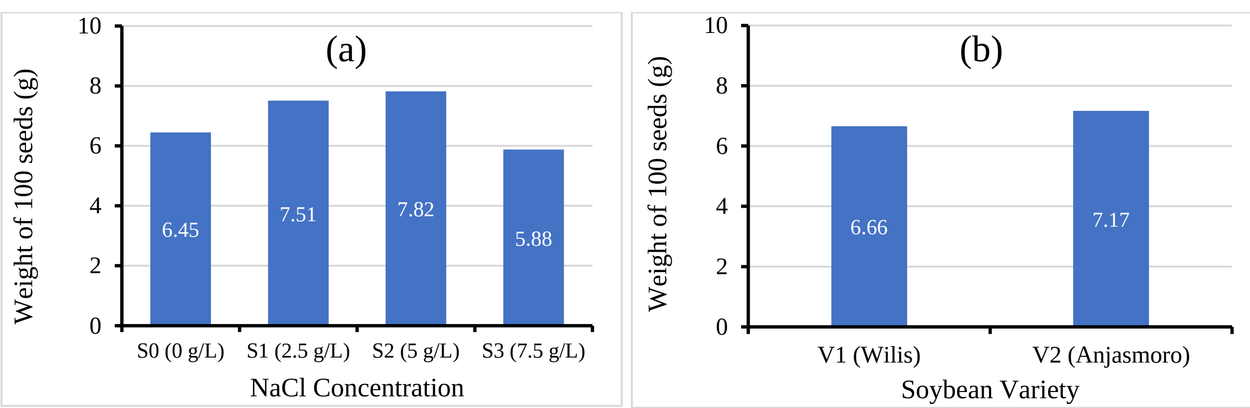

Figure 3. The average weight of 100 seeds due to single factor treatment: (a) NaCl concentration, and (b) Variety (both factors are not significant)

study conducted by Gian *et al*. (2021) with four levels of NaCl salt concentration, namely without saline, 4 dS/m, 8 dS/m, 12 dS/m also showed that salinity treatment had no significant effect on the weight of 100 seeds in rice plants. According to Cabot *et al*. (2014), stated that salt stress accelerates rapid leaf aging, thereby reducing seed yield and consequently pod weight.

The application of the results of the study on the effect of salinity stress on soybean plants of the Wilis and Anjasmoro varieties on saline land has several possibilities on a larger scale (field), namely from an agricultural perspective it can increase soybean yields in high salinity areas, increase national food security, and optimize the use of irrigation water to reduce salinity stress. Meanwhile, from an economic perspective, it can increase farmers' income by increasing productivity and reducing soybean imports by increasing domestic production.

4. CONCLUSION

Based on the results of the study, it can be concluded that the interaction of NaCl concentration and variety has a significant effect on the number of leaves at 28 HST in the combination of NaCl 0 g/l and the Anjasmoro variety producing 5.50 leaves and the highest number of productive branches is in the combination of NaCl 7.5 g/l and the Wilis variety producing 4.25 branches. The single treatment of NaCl concentration did not have a significant effect on the parameters of plant height, number of pods, and weight of 100 seeds in soybean plants. The single treatment of variety also did not have a significant effect on plant height, number of pods, and weight of 100 seeds. This is because both varieties have the potential to have the same resistance to salinity stress, with the presence of soybean varieties that are tolerant to salinity can increase soybean productivity in high salinity areas.

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