Growth and Yield Responses of Hot Pepper *(Capsicum annuum L)* to Salinity Stress

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Abstract. Hot pepper productivity in coastal areas tends to be lower than that of in common arable areas. The main problem is salinity stress which hampers growth and suppresses yield. The use of tolerant genotypes is one of the most prospective approaches to overcome the low productivity of coastal areas. This study aims at evaluating several hot pepper genotypes against salinity stress. Five hot pepper genotypes were grown in salinity stress nutrient solutions with sand media arranged in a 3x5 factorial with a Completely Randomized Design in 3 replications. The first factor was the level of NaCl-stressing concentration consisting of 0 (control), 3750, and 7500 ppm NaCl; and the second factor was the hot pepper genotype consisting of five genotypes namely 'PBC396', 'Bogota', 'Ferosa', 'Kopay' and 'Keriting Hitam'. The results showed that the interaction between the NaCl concentration and the hot pepper genotypes had a significant effect on the canopy area. The 'Keriting Hitam' genotype showed a tolerant response to salinity stress at a concentration of 3750 ppm, while the 'PBC 396' genotype was relatively tolerant to salinity at a concentration of 7500 ppm. NaCl concentration level of 7500 ppm can inhibit the growth and yield of hot pepper up to 80%.

Keywords: Abiotic Stress, Hot Pepper, Salinity Tolerance.

1 Introduction

The increase of population, climate changes, and, consequently, land use threatens the global crop production [1], not exceptionally, the national hot pepper in Indonesia. Therefore, extending the planting areas to the marginal and less productive areas, such as coastal, is a strategic way out to cope with the supply-demand problems in the future. Coastal areas is one of huge potential land sources for the island country like Indonesia where it accounts for about 12 million hectares [2]. Unfortunately, the major constraint of the soil in coastal areas is high salinity level which hampers crop productivity [3] [4].

The osmotic impact of salts dissolved in soil solution may impair plant growth by lowering water potential in leaves and tissues [5]. Salinity stress interferes every stage of plant growth and, consequently, the yield, as it impedes photosynthesis and other

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metabolic activities [6]. The severity of the impact is depend upon the magnitude of the stress and type of the plant [7].

Effective approaches should be taken to alleviate salinity stress when coastal areas to be used to buffer for the national hot pepper production. They are soil remediation, salt-tolerant crop improvement, or both of them simultaneously. Saline soil remediation may include fresh water leaching, gypsum and sulfur amelioration, or organic fertilizer or mulch application [8], or microorganism remediation [9]. However, these methods are, most of the time, short-lived and unaffordable. The most prospective control manner to mitigate the salinity stress is the use of cultivars which are tolerance to salinity stress [10].

The objective of this study was to evaluate the growth and yield responses of several hot pepper genotypes to salinity stress. These genotypes were considered the most tolerant group in selection for salinity tolerance at juvenile stage (data not presented).

2 Methods

Plant materials were seeds of a genotype (PBC396), a local accession ('Keriting Hitam') and three commercial non hybrid hot pepper cultivars ('Bogota', 'Ferosa' and 'Kopay'). Those genotypes were the most salt-tolerant group previously selected at juvenile stage out of 30 genotypes evaluated for salinity tolerance.

A factorial of 3x5 with 3 replication was set up out in a greenhouse of Dep. Crop Production, Fac. Agriculture, University of Bengkulu, from January to June 2020. The first factor was the level of salt concentration, i.e. 0 (control), 3750 and 7500 ppm NaCl. The second factor was the genotypes (PBC396, ('Keriting Hitam', 'Bogota', 'Ferosa' and 'Kopay'). Each experimental unit consisted of two plants.

The seeds were sown in 72-cell trays filled with a mix media of cow manure and mineral soil of 2 :1 (w/w). The seedlings were watered twice a day. At three weeks after seeding, the seedlings were transplanted into polybags (5 L) filled with dirt-free sand placed on nutrient buckets. The sand media were connected to the nutrient solution by a flannel-fabric wick. For a week after transplanting, the plants were grown in a NaCl-free nutrient solution. The nutrient solution was made by diluted AB mix hydroponic (Joro AB mix) supplemented with 0, 3750, or 7500 ppm NaCl. Each pack of AB mix fertilizer was diluted in 500 ml water as the Stock A and Stock B. Stock NaCl of 100.000 ppm was made by diluting 100 g NaCl in 1 L solution. The working solution of 60 L in each treatment was made following Table 1. The plants were maintained in a stress condition throughout the experiment.

Table 1. The amount of stock A, B, and NaCl, and tap water in the formulation of 60 L working solution in each salinity stress level.

NaCl Stress level	Stock A (ml)	Stock B (ml)	NaCl Stock (ml)	Tap water (ml)
0 ppm (control)	300	300	0	59400
3750 ppm	300	300	2250	57150
7500 ppm	300	300	4500	54900

Plant maintenance were nutrient refilling, replanting, plant staking, pruning, and pest controlling. The nutrient solution was refilled when the nutrient solution in the nutrient container run out. At 7 days after planting the unhealthy plants or dead plants were replanted by the spare seedlings. Plant staking was carried out starting at 3 weeks after transplanting (WAT) by placing 1 m long bamboo stakes besides the plant to support upright stand. The main stem of each plant was, then, bind to its stake by a plastic rope. Pruning was performed by removing all axillar branches growing below the first dichotomous branch. Pests and diseases control was carried out preventively every week by spraying a mix pesticide of Mankozeb-Difenokozanol fungicide, Profenos insecticides, and Pyridaben acaricides with the rate of 1 ml/L each of them [11]. Harvesting was done on any fruit which its color at least 50% turn to red. Harvesting was done at intervals of 5 days until all the fruits formed from the first flowering period run out.

Measurements were taken on plant height, fresh root weight, fresh shoot weight, fruit length, fruit diameter, fruit weight per plant. Plant height was measured using a meter from the base of the stem to the highest growing point, measurements were made one week after transplanting until the plants entered the generative phase. Canopy area was determined by taking the measurement on the largest and the shortest diameter (L) of the plant canopy and then calculating the elliptic equation (π x 0.5 x W x 0.5 x L) in the first harvest. Fresh roots and shoots were weighed using the SF-400 digital balance after the last harvest. Fruit length was measured from the base to the tip of the fruit, excluding fruit petiole, at 10% of each harvest. Fruit diameter was measured using a caliper at the base, the middle and the tip of the fruit, measurements were made at 10% of the fruit each harvest. Fruit weight per plant was the total weight of the fruits from the first to the last harvest.

The data was analyzed statistically using the analysis of variance (ANOVA) at α=5%, the trend response of the traits to the salt concentration were performed by polynomial orthogonal, and the main comparison of genotypes was performed by the Duncan's Multiple Range Test (DMRT) at α=5%. The tolerance index was calculated using the Stress Tolerance Index (STI) [12].

$$\mathrm{STI} = \frac{(\mathrm{Y_p}\ x\ \mathrm{Y_s})}{(\bar{Y}_{\mathrm{p}})^2} \tag{1}$$

Where STI, Yp, Ys, and $\bar{Y}$p were the Stress Tolerance Index, observed value at control, observed value at stress condition, and the average value observed at control of all genotype evaluated, respectively.

The response of genotype was classified following the formula:

$$\mathrm{class} = \frac{(\mathrm{STIh} - \mathrm{STIl})}{3} \tag{2}$$

Where STIh and STIl were the highest and the lowest STI value, respectively.

3 Results

According to data from the Bengkulu Climatology Station, the climatic conditions during the research showed that the monthly average temperature ranged from 27.1°C – 27.8°C and the average humidity 84%. The condition was suitable for hot pepper. At the beginning of the experiment, all seedlings grew normally and, at four weeks old, they were ready to be transplanted. The first week after transplanting, all plants were kept in a non-stress condition allowing transplant recovery from transplanting stress.

Electric conductivity (EC) of the nutrient solution increases as the NaCl concentration increases. In control, NaCl-free solution, the EC value was 3.0 mS/cm. Meanwhile, the EC value of nutrient solution supplemented with 3750 and 7500 ppm NaCl were 11.0 and 15.4 mS/cm, which were classified low and medium, respectively. However, the EC value in the sand media measured at 12 WAT was unexpectedly higher compared to that in the nutrient solution. At the concentration of 0, 3750 and 7500 ppm NaCl, the EC values were 5.6, 22.7, and 29.9 mS/cm, respectively. The conductivity value of sand media is almost close to the conductivity value measured in the seawater, 38.3 mS/cm.

In the stress-free treatment, the plant growth pattern followed a sigmoid pattern. In the first 2 weeks, the increase in plant height is relatively small, but from the third week to the 7th week the plant height increase occurs very quickly, and starting from the 8th week the plant height increase begins to decrease. From the first week to the seventh week, the plant height of the 'Kopay' cultivar and the local cultivar 'Black Curly' did not differ. However, starting from the eighth week, the 'Kopay' cultivar was higher than 'Black Curly'. From the second week, the two genotypes showed higher growth compared to the other three genotypes. Even though it is lower than 'Kopay' and 'Keriling Hitam', the 'Ferosa' cultivar tends to be higher than the 'PBC 396' genotype and 'Bogota' cultivar. Stress of 3750 ppm NaCl significantly suppressed the growth of chili plant height. The response to this stress varies between genotypes. In general, plants experience the effects of stress from the second week in stress, but plant growth continues until they produce fruit. The lowest plant height was shown by the genotype 'PBC 396', while the other four genotypes were relatively the same. However, if you look at the differences in growth compared to the control, 'Kopay' and 'Keriting Hitam' experienced the highest decrease in plant height. At 7500 ppm NaCl stress, all genotypes were severely suppressed in their growth, and there was no significant increase in height since the 5th week. There was no difference between the five genotypes, but 'Ferosa' showed a decrease in measurement results due to the death of some of the observed samples (Fig. 1).

Harvesting was performed starting at the age of 71 HST with a span of 5 days. The control treatment for all genotypes produced fruits so that harvesting could be carried out, as was the case with the concentration of 3750 ppm NaCl solution. In the treatment of 7500 ppm NaCl concentration, all genotypes could not be harvested because the plants had died before producing fruit. This was probably due to high accumulation of NaCl in the sand media which was about threefold higher compared the actual concentration of nutrient solution.

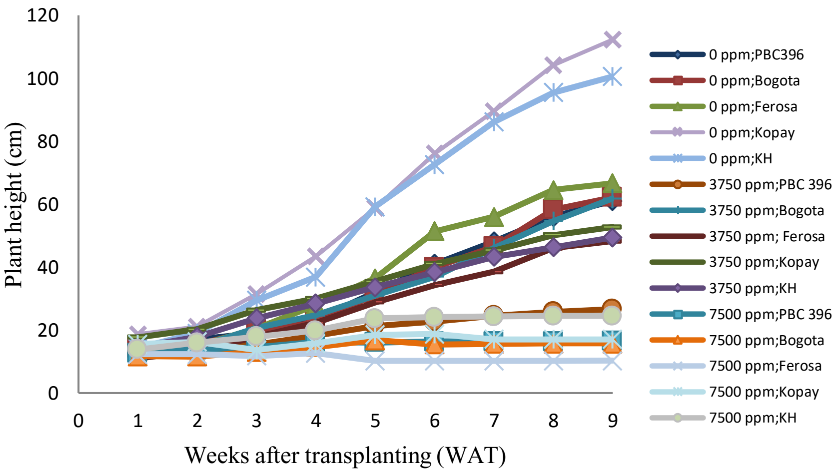

Figure 1. Curve of plant height**.**

1.1 Plant Growth and Yield Responses to the Increase of NaCl Concentration

Salinity harmed all growth and yield variables of hot pepper plants. The higher the concentration of NaCl solution the stronger inhibition on plant growth. Orthogonal Polynomial regression model of the effect of increasing NaCl concentration to plant height followed the equation of Y = -0.0085x + 80.238 with the coefficient of determination (R^2) = 0.9669. This indicated that every one-unit increase in NaCl concentration decreased the plant height by 0.0085 cm. The value of determination coefficient explained the variation in plant height which can be explained by this equation was as high as 96%. The response of root fresh weights formed a quadratic relationship pattern with the regression equation of Y = 6E-07x^2 + 0.0078x + 24.63. That means every one-unit increase in NaCl concentration reduced the fresh root weight by 0.0078 g. The coefficient of determination (R^2) of 0.8048 explained that the variation in fresh root weight that can be explained by the equation was 80.48%. The response of shoot fresh weight formed a linear relationship with the regression equation Y = -0.0196x + 133.46 and the coefficient of determination (R^2) = 0.7844. This means that for every one-unit increase in NaCl concentration, the fresh shoot weight of chili plants will decrease by 0.0196 g. The variation in fresh crown weight that can be explained by this equation is an average of 78.44%. The response of fruit length to increasing NaCl concentration forms a quadratic relationship pattern with the regression equation Y = -1E-07x^2 - 0.0002x + 8.9478 and R^2 = 0.8435. Each one-unit increase in NaCl concentration will decrease fruit length by 0.0002 cm. The determination value explaining the variation in fruit length which can be explained through this equation is 84.35%. The fruit diameter response forms a quadratic relationship pattern with the regression equation Y = -7E-08x^2 + 0.0002x + 5.2677 and R^2 = 0.8877. This means that every one-unit increase in the concentration of NaCl treatment will decrease the diameter of the fruit by 0.0002 mm. The variation in fruit diameter that can be explained by this equation is 88.77%.

The response of the weight of the fruit planted formed a quadratic relationship pattern with the regression equation $Y = 4E\text{-}06x^2 - 0.0426x + 117.4$ and $R^2 = 0.9448$. That is, every one-unit increase in NaCl concentration will decrease the fruit weight of the plants by 0.0426 g. This equation can explain 94.48% of the variation in fruit weight of the plants (Table 1).

Table 1. Hot pepper plant response to the increase of NaCl concentration in the nutrient solution.

Variable	Regression equation of Orthogonal Polynomial	Determination (R^2)	Trend Response
Plant height	$y = -0.0085x + 80.238$	0.9668	Linear
Root fresh weight	$y = 6^{E-07}x^2 - 0.0078x + 24.63$	0.8048	quadratic
Shoot fresh weight	$y = -0.0196x + 133.46$	0.7844	Linear
Fruit length	$y =-1^{E-07}x^2 - 0.0002x + 8.9478$	0.8435	Quadratic
Fruit diameter	$y =-7^{E-08}x^2 - 0.0002x + 5.2677$	0.8877	Quadratic
yield	$y = 4^{E-06}x^2 - 0.0426x + 117.4$	0.9448	Quadratic

1.2 Comparison of Growth and Yield among Hot Pepper Genotypes

The genotype had a significant effect on plant height, but had no significant effect on fresh root weight, fresh shoot weight, fruit length, fruit diameter, and fruit plant weight. DMRT at α=5% indicated that the ‘Kopay’ and ‘Keriting Hitam’ had better vegetative growth compared to other genotypes (Table 2). Meanwhile, the genotype of ‘PBC 396’, ‘Bogota’, and ‘Ferosa’ were about the same in height.

Table 2. Data on average growth of five hot pepper genotypes against salinity stress.

Genotype	Plant height (cm)	Root Fresh Weight (g)	Shoot fresh weight (g)	Fruit length (cm)	Fruit diameter (mm)	Fruit weight (g)
‘PBC 396’	34.74 b	6.61	51.02	2.75	3.98	33.83
‘Bogota’	46.58 ab	8.36	63.45	5.34	2.87	32.91
‘Ferosa’	41.73 b	5.99	42.05	3.98	1.87	29.63
‘Kopay’	60.68 a	9.47	71.32	8.05	2.65	66.77
‘Keriting Hitam’	58.15 a	6.84	71.26	5.30	3.33	45.99

Note: Numbers in the same column followed by the same letter are not significantly different according to DMRT at α=5%.

1.3 Stress Tolerance Index

The index value of each genotype was ranked from the highest value to the lowest value. At the concentration of 3750 ppm NaCl, the highest index value was 0.51 and the lowest index value was 0.24. At the concentration of 7500 ppm, the highest index value was 0.29 and the lowest index value was 0.04. The difference in index values was then divided by three to obtain the response category of tolerance to salinity stress of the genotype. At the concentration of 3750 ppm tolerant genotypes had index values ≥ 0.43, moderate genotypes ≤ 0.35 – ≥0.43 and sensitive genotypes ≥ 0.35. At the concentration of 7500, tolerant genotypes index ≥ 0.21, moderate genotypes ≤ 0.13 – ≥0.21 and sensitive genotypes ≥ 0.13. The results of the stress tolerance index analysis [12], hot pepper plants to salinity stress was presented in Table 3 and 4.

At medium stress condition, the ‘Kopay’ exhibited the highest STI value and categorized tolerance. The ‘Bogota’ and ‘Keriting Hitam’ were categorize moderately tolerance. Meanwhile, the ‘PBC 396’ and ‘Ferosa’ showed the lowest STI and categorized sensitive. However, at 7500 ppm NaCl, the‘PBC 396’ showed the highest STI among genotypes and categorized tolerance, while the others were sensitive.

Table 3. Stress Tolerance Index value of five genotypes at NaCl-stressing concentration of 3750 ppm.

Genotype	Plant height	Root Fresh Weight	Shoot fresh weight	Fruit length	Fruit diameter	Fruit weight	STI	Category
‘PBC 396’	0.34	0.09	0.04	0.19	1.22	0.02	0.32	S
‘Bogota’	0.57	0.28	0.40	0.80	0.66	0.08	0.47	M
‘Ferosa’	0.63	0.21	0.21	0.67	0.43	0.11	0.38	S
‘Kopay’	1.06	0.22	0.11	1.79	0.52	0.07	0.63	T
‘Keriting Hitam’	0.92	0.08	0.25	0.77	0.90	0.09	0.50	M

Note: T: tolerance, M: moderately tolerance, S: sensitive

Table 4. Stress Tolerance Index value of five genotypes at NaCl-stressing concentration of 7500 ppm.

Genotype	Plant height	Root Fresh Weight	Shoot fresh weight	Fruit length	Fruit diameter	Fruit weight	STI	Category
‘PBC 396’	0.26	0.12	0.03	0.33	1.41	0.03	0.36	T
‘Bogota’	0.24	0.05	0.01	0.00	0.00	0.00	0.05	S
‘Ferosa’	0.22	0.03	0.00	0.00	0.00	0.00	0.04	S
‘Kopay’	0.50	0.05	0.01	0.00	0.00	0.00	0.09	S
‘Keriting Hitam’	0.58	0.04	0.02	0.00	0.00	0.00	0.11	S

Note: T: tolerance, S: sensitive

4. Discussion

The climatic condition during the experiment was suitable for hot pepper plant. A good temperature for chili plants is between 21 and 30 °C. with an average of 18 °C [13]. These implied that the effect of other environmental factors instead of the salinity treatment could be ignored.

The results showed that the higher the NaCl concentration given to the plant growth media, the response to the plant growth was the average value decreased with the higher level of NaCl concentration given. The decrease occurred presumably due to each increase in NaCl concentration. Plants experience poisoning, causing hot pepper plants grew stunted and plants have difficulty in absorbing water. In mung bean, the level of soil salinity with high NaCl content, suppresses plant growth which causes the plants to become poisoned [14]. Symptoms of poisoning observed in hot pepper plants were yellowing leaves and then drying which similarly was found in peanuts [15].

The results showed that the higher concentration of NaCl given to chili plants showed a response to the variable plant height observation. stem diameter. number of dichotomous branches. dichotomous height. fresh root weight. dry root weight. fresh header weight. dry crown weight. fruit length. fruit diameter. number of fruit and fruit weight planted. Where all the observed variables decreased along with the higher concentration of NaCl applied. Saline soils have a high NaCl content which suppresses plant growth. Salinity affects almost all physiological and biochemical aspects of plants resulting in decreased growth and yield of rice plants [16].

Response of plant height indicated that increasing the concentration of NaCl could inhibit plant growth of the five genotypes of red chili. The higher the concentration of NaCl, the severer the growth inhibition. The increase in salinity stress significantly reduced plant height which caused plant growth to stagnate [15].

Increasing the concentration of NaCl causes a decrease in root weight and shoot weight of chili plants. The decrease occurs because plants have difficulty absorbing water and the effect of increasing NaCl concentrations is toxic to plants which can disrupt metabolic processes resulting in stunted plants [17]. The decrease in shoot biomass weight was greater than that of roots. Differences in root weight and shoot weight in each genotype was due to differences in the ability of plants to absorb water and nutrients into plants [18]. Yield response of red chili plants from fruit length, fruit diameter, and the weight of the fruit indicated that every increase in the concentration of NaCl applied decreased the yield of chili plants. At a concentration of NaCl 7500 ppm, except the'PBC 396' all hot pepper genotypes did not set fruit. A plant will experience adaptation in a state of stress. Plants will adapt to extreme environments so that tolerant plants are obtained [19]. Plant adaptation to the environment is a form of interaction between genetics and the environment [20].

5. Conclusion

The genotype 'Kopay' and Keriting Hitam'Black showed a tolerant response to salinity stress at a concentration of 3750 ppm. While the 'PBC 396' genotype was tolerance to salinity at a concentration of 7500 ppm. The NaCl concentration level of 7500 ppm can reduce the growth and yield of red chili plants by 80%.

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