Journal of Agricultural Sciences
E-ISSN : xxxx-xxxx
P-ISSN : xxxx-xxxx

The Response of Shallot (*Allium ascalonicum*) to Salinity Stress

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Abstract. Shallot (*Allium ascalonicum*) cv Bima Brebes is the cultivar that was most widely cultivated in shallot production centers on Java Island. The increasing rate of land use conversion from agricultural to non-agricultural land caused the shallot cultivation to be directed to marginal lands, including land with high salinity. This study aimed to determine the effect of the salinity level on the growth and yield of shallots and to determine the highest level of salinity that can be tolerated by shallots. This experiment was carried out from October to December 2022 at the Experimental Station of Swadaya Gunung Jati University. The location is located in Cirebon City, West Java, Indonesia. The research method used was the experimental method with a completely randomized design (CRD). The treatment was salt concentration consisted of 5 levels i.e., 0 ppm, 1250 ppm, 2500 ppm, 3750 ppm, and 5000 ppm. Each treatment was repeated 5 times so that there were 25 experimental units. Each experimental unit consisted of 10 polybags of shallot plants. The results showed that salt concentration significantly inhibits the growth and yield of shallot at all of the measured parameters i.e., plant height, number of leaves, root length, root volume, plant dry weight, plant growth rate, number of tubers, tuber diameter, fresh tuber weight, and dry tuber weight. The salt concentration of 1250 ppm is the tolerance limit for salinity stress for shallots.

Keywords: Bima Brebes, salinity, shallot, tolerance

INTRODUCTION

Shallot (*Allium ascalonicum*) is one of the leading horticultural commodities and has good prospects for meeting national consumption, a source of income for farmers, and foreign exchange (Lestari & Palobo, 2019). The importance of this commodity is not only as a seasoning related to its aroma but also medicinal properties due to the content of enzymes that play a role in improving health status, the content of anti-inflammatory, anti-bacterial, and anti-regeneration substances (Istina, 2016).

Along with the increasing population, a lot of land has been converted into non-agricultural land, this has led to a decrease in productive agricultural land (Latuharhary & Saputro, 2017). Marginal land use is an alternative that can be done for shallot cultivation. The expansion of shallot cultivation areas began to penetrate land near the coast. However, the problem faced by farmers in shallot cultivation is the entry of seawater into irrigation canals which causes the land to experience salinity stress (Rahayu *et al*., 2019).

Agricultural land near the coast that has the potential to experience salinity stress is around 12.020 million ha, 6.20% of Indonesia's total land area. In addition, on irrigated agricultural land, an increase in capillarity from a shallow groundwater table will cause salts to enter the root zone (Karolinoerita & Annisa, 2020). The problem of salinity stress is also found in peatlands (Junandi *et al*., 2019).

This study aims to determine the response of shallots to salinity and determine the tolerance limit of shallots cv Bima Brebes to salinity stress. The results of this study can be useful information in efforts to develop shallot cultivation in coastal areas.

LITERATURE

Salinization occurs due to an increase in soluble salts ($NaCl$, Na_2CO_3, Na_2SO_4) in the soil (Ma'ruf, 2016; Rachman et al., 2018; Rahayu *et al*., 2019). Salinity stress can suppress growth and reduce plant yields, especially in plants belonging to the glycophyte group or which are sensitive to salinity stress (Purwaningrahayu & Taufiq, 2017). Shallots are plants that are sensitive to salinity stress (Rahayu *et al*., 2019). The results showed that an increase in soil salinity reduced the height of onion plants but had no effect on the number and weight of shallot bulbs (Syamsiah *et al*., 2020). In garlic, an increase in salt concentration negatively affected growth, yield, and tuber quality (Shama *et al*., 2016).

Plants growing on saline soils will experience stress due to two things: osmotic stress and ionic toxicity. This stress will affect physiological processes such as photosynthesis, cell metabolism, and plant nutrition (Safdar *et al*., 2019). When plants are exposed to salinity, their first response is to close stomata and reduce cell elongation, especially in shoots. Furthermore, the accumulation of toxic ions by plants will cause inhibition of metabolism, premature aging, and finally cell death (Isayenkov & Maathuis, 2019).

Salinity can reduce the chlorophyll index and carotenoid content in leaves. High levels of Na in leaves due to salinity can reduce potassium uptake by plants (Astaneh *et al*., 2018). A decrease in the chlorophyll index also occurred in soybeans (Purwaningrahayu & Taufiq, 2017). *Acassia mangium* plants respond to salinity stress by reducing the stomata index, increasing stomata size, chlorophyll content, and the number of tracheal (Ma'ruf, 2016).

METHOD

The experiment was conducted in the experimental garden, Universitas Swadaya Gunung Jati, from October until December 2022. The materials used were shallot cv Bima Brebes seeds, sodium chloride (NaCl), NPK 16:16:16 fertilizer, planting medium (soil and sand 1:1 v/v), and polybags.

The experimental method was used, with a randomized complete design. The treatment was a concentration of NaCl as salinity stress, which consisted of 5 treatment levels, namely 0 ppm (control), 1250 ppm, 2500 ppm, 3750 ppm, and 5000 ppm. Each treatment level was repeated 5 times so that there were 25 experimental units. Each experimental unit consisted of 10 polybags. Each polybag consists of one shallot plant. The polybags used are polybags without holes. The NaCl solution is sprinkled on the planting media every other day with a volume of 150 mL for one water. Watering is done from the planting until before harvest.

Variables observed included growth vigor, plant height, number of leaves per clump, visual toxicity score, root length, root volume, plant dry weight measured at 42 days after planting (DAP), plant growth rate (35-42 DAP), number of tubers, tuber diameter, fresh tuber weight per clump and experimental unit, and dry tuber weight per clump and per experimental unit were measured at harvest. The poisoning score is calculated by the formula:

$$Poissoning\ score = \frac{number\ leaves\ with\ chlorosis}{total\ number\ leaves}\ x\ 100\%$$

DISCUSSION

Salt concentration has a significant effect on shallot growth variables (Table 1). Salt concentration causes a decrease in plant height, number of leaves, length and volume of root, plant dry weight, and plant growth rate. Symptoms of NaCl poisoning begin to appear at a concentration of 2500 ppm. However, the dry weight of the treated plants was significantly lower than that of the control. Furthermore, the growth rate of plants treated with salt was slower than the control.

High salt concentrations inhibit plant growth. This inhibition is caused by osmotic and oxidative stress, as well as ion toxicity (Alam *et al.*, 2023). However, the failure to germinate under salinity stress is due to the high Na accumulation compared to osmotic stress (Akbarimoghaddam *et al.*, 2011). In onions (*Allium cepa*), high salt concentrations delay and even reduce germination (Alam *et al.*, 2023; Singh & Gopal, 2019).

Table 1. Shallot growth variable at different salt concentrations

Treatment (ppm)	Growth vigor (%)		Plant height (cm)		Number of leaves		Poisoning score (%)		Root length (cm)		Root volume (mL)		Dry weight (g)		Plant growth rate ($g.day^{-1}$)	
0	100	b	38.72	c	15.56	c	0	a	19.70	b	2.2	c	3.31	c	1.22	b
1250	100	b	38.07	c	11.84	b	0	a	16.34	ab	1.7	bc	1.93	b	0.42	a
2500	98	b	37.29	bc	11.80	bc	6.06	b	15.18	a	1.5	b	1.96	b	0.29	a
3750	92	a	35.12	ab	9.36	ab	10.24	c	14.28	a	1.4	ab	1.53	ab	0.38	a
5000	92	a	33.66	a	7.24	a	13.08	d	12.96	a	0.9	a	1.36	a	0.34	a

Note: The average number followed by the same letter in the column is not significantly different according to the LSR Test at an error level of 5%.

Plant height significantly decreased with increasing salt concentration (Table 1). The decrease in plant height began to appear at 2500 ppm treatment. The number of leaves even began to decrease at a salt concentration of 1250 ppm. Salinity stress also reduces the height of Allium porrum plants (Kiremit & Arslan, 2016). The stunted growth in plant height occurs due to osmotic pressure which causes it to be difficult for plants to absorb water and the effect of excessive Na and Cl ions (Romadloni *et al.*, 2018). The lack of water availability will inhibit plant growth (Latuharhary & Saputro, 2017).

Plants stressed by salinity experienced growth inhibition. This can be seen from the number of leaves which decreases as the concentration of salinity increases (Table 1). Hadianti & Damanhuri, (2019) stated that cell formation and enlargement were hampered due to high salt levels, thereby reducing the number of leaves and plants would grow stunted.

The level of poisoning increases with increasing salt concentration. This is because salinity stress will inhibit the formation of chlorophyll (Astaneh *et al.*, 2018; Ma'ruf, 2016; Purwaningrahayu & Taufiq, 2017). Reduced levels of chlorophyll will cause the leaves to chlorosis, then necrosis and eventually dry out. Reduced levels of chlorophyll will affect the rate of photosynthesis and plant growth rate. It can be seen that the dry weight of plants decreases as the salt concentration increases. In addition, the growth rate was also slower than the control.

Salinity stress inhibits root growth. Table 1 shows that both root length and volume decreased with increasing salt concentration. Stunted root growth is caused by high accumulation of Na which inhibits absorption of other nutrients. This results in disruption of the root growth process in the vegetative phase (Junandi *et al.*, 2019). In the first stage of the plant that face salinity stress, osmotic stress will occur inte roots due to the accumulation of phytotoxic ions. Furthermore, plants will experience ion toxicity due to an imbalance of nutrients in the cytosol (Hernández, 2019). High concentrations of NaCl in the soil can increase the osmotic pressure of the solution, causing a decrease in cell turgidity and reducing the ability of plants to absorb water (Dachlan *et al*., 2013; Wibowo *et al*., 2016).

High concentrations of NaCl reduced plant dry weight and plant growth rate (Table 1). The dry weight of the plants in the control was significantly higher than those treated with NaCl. The dry weight decreased as the concentration of NaCl increased. Increasing the salt concentration in the root zone will reduce water uptake thereby reducing plant growth (Kiremit & Arslan, 2016). The stunted growth rate is a form of plant response when experiencing salinity stress due to the supply of water and nutrients that are difficult for plants to absorb. Salinity stress affects the rate of photosynthesis. At low concentrations, salt will encourage the rate of photosynthesis but at high concentrations, it will inhibit the rate of photosynthesis (Safdar *et al*., 2019). This resulted in reduced plant dry weight.

Table 2. Shallot yield component and yield variables at different salt concentrations

Treatment	Bulb Number	Bulb diameter (mm)	Fresh weight of bulb per clum (g)	Fresh weight of bulb per plot (g)	Dry weight of bulb per clump (g)	Dry weight bulb per plot (g)
0 ppm	7,40 b	15,72 c	18,89 c	124,45 c	16,81 c	110,80 c
1250 ppm	6,12 ab	13,03 b	12,94 b	88,08 b	11,87 b	79,91 b
2500 ppm	6,64 ab	12,47 b	13,01 b	92,86 b	11,72 b	83,55 b
3750 ppm	5,56 a	11,90 b	8,73 a	54,24 a	7,92 a	48,78 a
5000 ppm	4,68 a	9,42 a	6,86 a	45,31 a	6,10 a	39,96 a

Note: The average number followed by the same letter in the column is not significantly different according to the LSR Test at an error level of 5%.

Salinity stress significantly reduced the yield components and yield of shallots (Table 2). The most significant decrease occurred at a salt concentration of 3750 ppm, both in the number of tubers, tuber diameter, fresh tuber weight, and dry tuber weight. When plants experience salinity stress, the water potential in the soil is lower than that of plant cells. As a result, the plant will experience a lack of water, which causes the closing of stomata to conserve water. Stomata closure will reduce CO_2 fixation and reduce the rate of photosynthesis (Ma'ruf, 2016; Safdar *et al*., 2019). In some types of vegetables, the decrease in the rate of photosynthesis is also due to salinity stress reducing the concentration of chlorophyll in the leaves (Machado & Serralheiro, 2017; Purwaningrahayu & Taufiq, 2017; Zeeshan *et al*., 2020).

The decrease in the yield component and yield of the Bima Brebes cultivar indicates that the Bima Brebes cultivar is susceptible to salinity stress. In cultivars that are tolerant to salinity stress, stress reduces growth but does not affect plant yields (Najjaa *et al*., 2018; Nanda Hadianti & Damanhuri, 2019; Zeeshan *et al*., 2020). Decreased tuber size and weight also occurred in onions that were experiencing salinity stress (Alam *et al*., 2023). In soybeans, salinity stress causes pods not to form in sensitive cultivars (Purwaningrahayu & Taufiq, 2017).

CONCLUSION

Salt concentration affects the growth and yield of shallot cv. Bima Brebes. The number of leaves per clump, visual toxicity score, root length, root volume, plant dry weight, plant growth rate, number of tubers, tuber diameter, fresh tuber weight and dry tuber weight significantly decreased with increasing salt concentration. Salinity concentration of 2500 ppm is the tolerance limit for shallot cv. Bima Brebes.

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