

## Morpho-anatomy and physiology of red galangal (*Alpinia purpurata*) and white galangal (*Alpinia galanga*) under some salinity stress levels

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**Abstract.** Setiawati T, Susilawati A, Mutaqin AZ, Nurzaman M, Annisa, Partasasmita R, Karyono. 2018. Morpho-anatomy and physiology of red galangal (*Alpinia purpurata*) and white galangal (*Alpinia galanga*) under some salinity stress levels. *Biodiversitas* 19: 809-815. Soil salinity is one of the most urgent issues in agriculture as it can reduce plant growth and productivity. Efforts on development of galangal plant on saline soils are still encountering some obstacles such as lack of information on the galangal types that are tolerant to saline condition. The purpose of this study was to determine morpho-anatomical and physiological responses of red galangal (*Alpinia purpurata* (Vieill.) K. Schum.) and white galangal (*Alpinia galanga* (L.) Willd.) to salinity stress treatments. This research used a Randomized Block Design (RBD) assigned in a factorial treatment design of two factors, i.e., (i) species of galangal consisting of two levels i.e., red galangal and white galangal, (ii) NaCl concentration consisting of five levels, i.e., 0‰, 3‰, 6‰, 9‰ and 12‰. Each treatment was three replicates. Observation was done on the growth parameters when the plants showed wilting symptoms. The observed data were subjected to Analysis of Variance (ANOVA), followed by a post hoc Duncan Multiple Range Test (DMRT) at  $\alpha$  5% when the treatment effect was significant. The results showed that salinity stress treatment significantly reduced the plant height increase, leaf area, dry weight, stomata density, chlorophyll content and increased thickness of root epidermis, and proline content in both species of galangal. Red galangal was more tolerant than white galangal.

**Keywords:** Galangal, morpho-anatomy, physiology, salinity stress

### INTRODUCTION

Galangal is one of the herbal ingredients that have been widely used by the community as traditional medicine. The utilization of galangal as a herbal medicine material is increasingly widespread along with the discovery of its various biological activities such as immunomodulator (Weidner et al. 2007), high blood pressure lowering capacity, and fertility enhancer by increasing the number and motility of sperm (Chudiwal et al. 2010). Active substances of acetoxychavicol acetate (ACA) contained in galangal can inhibit the development of HIV (Ying and Baoan 2006), and can serve as antitumor, antioxidant and antimicrobial (Vankar et al. 2006). There are two kinds of galangal, i.e., the white tuber galangal called white galangal (*Alpinia galanga* (L.) Willd) commonly used as food seasonings and the red tuber galangal called red galangal (*Alpinia purpurata* (Vieill.) K. Schum) used as medicine (Lestari 2005).

The development of traditional medicine industry and other industries using galangal as raw material causes galangal demand tends to increase in the recent years, which necessitates cultivation efforts that can ensure the continuous availability of galangal. One of the attempts to increase the galangal production is by expanding the planting area. Land that has good prospects for agricultural development is marginal land, but technological innovation is required to improve the productivity of the marginal land

(Yuwono 2009), such as saline soil (Akbar 2010). Saline soil is a soil containing high dissolved NaCl salt with a pH of <8.5 and electrical conductivity of > 4 mmhos/cm so that it can interfere the plant growth (Follet et al. 1981), and consequently, it can decrease crop productivity.

Salinity affects many physiological and morphology processes of a plant by affecting the osmotic potential of soil solution and ion absorption and mineral accumulation (Ramezani et al. 2011). Salinity induces a variety of disorders at the cellular and whole plant levels. Salinity stress is produced from a number of adverse processes including the toxicity of Na<sup>+</sup> and Cl<sup>-</sup> ion, the impairment of mineral nutrition, water status modification of plant tissue and secondary stresses such as an oxidative stress associated with the production of toxic reactive oxygen intermediates (Bajji et al. 1998). As reported by Munns and Tester (2008) that salt stress on plants leads to a reduction in growth as a consequence of some physiological responses, including alterations of ion balance, water status, mineral nutrition, stomatal behavior, photosynthesis efficiency, and allocation and utilization of carbon. Soil salinity can affect plant growth both physically (osmotic effects) and chemically (nutrients and/or toxicity effects). Plants will be more difficult to absorb water as the soil salinity content increases. Sensitive plants appeared suffering from drought even though the salt content is quite low. There is usually a progressive decrease in growth and yield as salinity increases (Ogle and John 2010).

In general, the response of plants to salinity can be seen from the morphology, anatomy, and physiology characteristics that are closely related to the production of plants in water-shortage environments (Li et al. 2006). Salt tolerant plants are able to minimize adverse effects by producing a series of anatomical, morphological and physiological adaptations (Hameed and Ashraf 2008). Under high salt content, especially chloride and sodium, plants modify their anatomical properties. This is caused by osmotic effects and ionic imbalances that affect plants metabolism. Anatomically, it affects cell division and expansion process and reduces the size of meristem, cortex and vascular cylinder (Singh and Chaturvedi 2014) to minimize the detrimental effects of salt stress (Younis et al. 2014).

One of the efforts in the management of saline land is by using plant species that have good adaptation and tolerance to high salt content. Research on salinity has been widely carried out but information on the effect of salinity on Zingiberaceae plant growth, especially galangal, has not been reported. Therefore, it is necessary to study the effect of salinity on the growth of red galangal plants (*A. purpurata*) and white galangal (*A. galanga*) based on morphological, anatomical and physiological characteristics as indicators for identification of saline tolerant types of galangal.

## MATERIALS AND METHODS

### Materials

The seedlings of red galangal and white galangal were obtained from Horticultural Seed Center, Department of Food Crops and Horticulture, Hegarmanah Village, Jatinangor Sub-district, West Java Province. Planting medium used consisted of a mixture of sand and manure (2: 1). NaCl solution was used for salinity stress treatments.

### Methods

This research used a Randomized Block Design (RBD) and a factorial treatment design. The treatments design included two factors: (i) species of galangal consisting of two levels, i.e., red galangal and white galangal, (ii) NaCl concentration consisting of five levels, i.e., 0‰, 3‰, 6‰, 9‰ and 12‰. Each treatment consisted of three replicates. The research was carried out in the Laboratory of Biosystem and Greenhouse, Department of Biology, Padjadjaran University, Sumedang, Indonesia during March-June 2017.

### Procedures

Three months old and homogenous seedlings of red galangal and white galangal were used in the study. Seedlings were planted in mixtures of sand and manure (2: 1) media contained in plastic pots and acclimatized for two weeks in a greenhouse before the salinity stress treatments were applied (Syakir et al. 2008). The salinity treatment was applied by watering the plants using NaCl solution according to a predetermined concentration (0, 3, 6, 9 and 12‰) every two days with the volume of field capacity

(Ramezani et al. 2011). Field capacity (FC) was determined based on a gravimetric method using the following formula:  $FC = (WW - DW) / DW \times 100\%$ , where WW = wet weight and DW = dry weight of soil. Pots with dry soil were weighed to obtain dry weight and were watered to a saturated level, allowed to drain for 24 hours and weighed again.

### Parameter measurement

Observations were made on the plant growth parameters when plants showed the symptom of wilting. The parameters observed were morphological, anatomical and physiological characteristics including plant height increase, leaf area, plant dry weight, stomata density, thickness of root epidermis, thickness of root cortex, root trachea number, chlorophyll and proline contents. Plant height increase is the difference between the plant height at the start of the treatment applied and that at the end of observation. The initial plant height was measured at the time of drought stress treatment was applied while the final plant height was measured when the plant showed wilting symptoms (24 days after the treatment was applied). Leaf area was measured using a leaf area meter CI-202 portable laser. Dry weight was measured by drying the plant materials in an oven at a temperature of 70°C to obtain a constant weight. Chlorophyll content was measured with chlorophyll meter Opti-Science CCM-20. The stomata density was observed using transparent nail polish applied to the leaf surface. The nail polish was spread to a small portion of the lower surface of the leaf and then peeled away slowly. Replica of stomata was examined under a light microscope with a magnification of 400 x (Shrestha and Kang 2016). Root anatomical observations included the thickness of epidermis and the thickness of cortex that were performed by making fresh preparations of the transverse incision of the roots and observed under a light microscope. Proline content was measured following the method by Bates et al. (1973). Leaf samples of 0.5 g were extracted with a 3% sulfo-salicylate solution. The filtrate was reacted with ninhydrin reagent, and then extracted with toluene. The red toluene containing proline was separated and the proline content was measured by using a spectrophotometer, absorbance was read at 520 nm wavelength. Proline content was determined using calibration curve and expressed as mg g<sup>-1</sup> fresh weight.

### Data analysis

Data analysis was done statistically using Analysis of Variance (ANOVA) and Duncan Multiple Range Test at significance level 95%. The relative stress tolerance was determined based on the salt stress sensitivity index (SI) calculated following the Fischer and Maurer (1978) equation, i.e.,  $SI = (1 - Y_p / Y) / (1 - X_p / X)$ , where: SI = index of salt stress sensitivity, Y<sub>p</sub> = the mean of a genotype in stress environment, Y = the mean of a genotype in non stress environment, X<sub>p</sub> = the mean of all genotypes in stress environment, X = the mean of all genotypes in non stress environment. The genotype is categorized tolerant to stress if it has a value of SI < 0.5, moderately tolerant if 0.5 ≤ SI ≤ 1, and susceptible if SI > 1.

## RESULTS AND DISCUSSION

### Plant height increase

The increase in plant height was measured by calculating the difference between the plant heights at the beginning of the treatment was applied and that at the end of the observation, i.e., when the plants showed wilting symptoms. In this study, plants exhibited the signs of wilting at 24 days after treatment was applied. Results showed that concentration of NaCl significantly affected the average of plant height increase ( $P < 0.05$ ) but the difference of galangal species and interaction of both factors have no significant effect ( $P > 0.05$ ) on the observed parameter. The mean plant height increase under various treatments of NaCl concentration can be seen in Table 1.

Table 1 shows that the average plant height decreased significantly with the increase of NaCl concentration of up to 12‰. At a NaCl concentration of 3‰, the average plant height was 1.17 cm, which did not differ significantly from that of the control treatment (0‰ NaCl) but differed significantly from other NaCl treatments. These results indicated that the galangal plant is able to adapt to NaCl concentration of 3‰. Yadav et al. (2001) stated that plant growth including the plant height increase would be inversely proportional to salinity levels. The present study result was in line with the study results of Kamrani et al. (2013) in *Brassica napus* L. showing that growth of plant height decreased as the salinity concentration increased to 350 mM. Increasing the salinity concentration caused a significant decrease in the height increase of galangal (Table 1). This condition was probably caused by the reduction in turgor pressure within the cells that restricted cell expansion (Jampeetong and Brix 2009); consequently, the increase of height was declined. Munns (1993) also reported that under salt stress, accumulation of salt did occur in older leaves that expedite their death. As a consequence of these leave loss, the supply of carbohydrate and growth hormone to the meristematic areas will decrease. This can lead to constrain the plant height growth that occurs in the stems apical meristem.

### Leaf area

Research results revealed that NaCl concentration significantly affected leaf area ( $P < 0.05$ ) but the interaction of the two factors had no significant effect ( $P > 0.05$ ) on the trait. Average leaf area of the two galangal species under various levels of NaCl concentration is presented in Table 2.

The average leaf area was significantly different among the two galangal species and also the NaCl concentration treatments (Table 2). The average leaf area of white galangal was higher than red galangal. This result showed that different species of galangal plants had different phenotypes (leaf areas), presumably due to differences in the genetic background of the two galangal species.

Table 2 also shows that the increase of NaCl concentration caused a significant decrease in the average leaf area of galangal. The average leaf area at the concentration of 6‰ NaCl (51.62 cm<sup>2</sup>) was not significantly different from that of the control treatment (NaCl 0‰). This result indicated that for the leaf area

variable, the galangal species were tolerant to NaCl concentrations of up to 6‰. Each plant has the ability to adapt and tolerate stress to a certain concentration. Leaf growth restriction under salinity stress is mainly due to the osmotic effects of salt around the roots, leading to decrease water supply to leaf cells (Cassaniti et al. 2012). Younis et al. (2014) reported that under high saline stress there was a reduction of water uptake by plants which created osmotic conditions and ionic toxicity resulting in smaller cell size and cell injury. This may cause a decrease in leaf area. Curtis and Lauchi (1987) found that the decrease in leaf area was caused by the decrease in cell size rather than the cell number. The decrease in cell size could be due to the decrease in osmotic potential of leaf cells. Similar to our results, Brugnoli and Lauteri (1991) also recorded that leaf area development was strongly reduced by salinity in cotton and bean.

### Dry weight

The present study showed that galangal species by NaCl concentration interaction effect was significant ( $P < 0.05$ ) on the plant's dry weight. The average dry weight due to interaction effects of both factors is shown in Table 3.

NaCl treatment caused a decrease in average dry weight of the galangal plant (Table 3). The highest average dry weight of the galangal plant (6.22 g) was observed in the white galangal treated with 6‰ NaCl, which was not significantly different from that of the same galangal species without NaCl (0‰ NaCl). The lowest average dry weight was found in red galangal at 12‰ NaCl (4.57 g). Similar to our result, Turan et al. (2009) also reported that the effect of salinity on corn growth showed a negative correlation. The 100 mM NaCl concentration significantly decreased the dry weight of the plant up to 45.46% as compared to the control (0 mM). Ceccoli et al. (2011) also reported similar results in *Chloris gayana* plants, where there was a decrease in total dry weight at high NaCl concentration (250 mM).

Dry weight is often measured to indicate the growth of plants and cells in response to saline environment (Bekheet 2015). The decrease of dry weight on salt-exposed plants was due to the destruction of salt-induced photosynthetic tissue, the reduction of water potential and high accumulation of Na<sup>+</sup> and Cl<sup>-</sup> (Ashraf et al. 2008). Also, according to Curtis and Lauchli (1986) increased salinity has an inverse relationship with stomatal conductance and net photosynthetic rate. This condition will cause reduction of the plant dry weight. According to Lopez et al. (2009), salinity stress will alter the metabolism to overcome the stress that causes growth to decrease. Also, this decrease is the effect of plant defense mechanisms to reduce greater salinity exposure.

### Stomatal density

The results of ANOVA showed that difference of galangal species, NaCl concentration, and its interaction did not significantly affect the stomatal density ( $P > 0.05$ ). Stomatal density in both species of galangal at different concentrations of NaCl is shown in Figure 1. Figure 1 shows that stomatal density did decrease along with the

increase of salinity in both species of galangal. The white galangal (*A. galanga*) had a higher average stomatal density than the red galangal at all NaCl concentrations. These results indicated that the white galangal plant was more tolerant to salinity than the red galangal. In the NaCl treatments, the lowest average stomatal density was found in 12‰ NaCl, i.e., 77.45 cells/wide field of view and 75.31 cells/wide field of view in red galangal and white galangal, respectively. Similar results were found on stomatal density in leaves of *Kandelia candel* (Qiu et al. 2007), *Simmondsia chinensis* (Ali et al. 2013), where the stomatal density did decline with the increase of salinity. Reginato et al. (2013) reported that NaCl treated *P. strombulifera* plants showed a significant decrease of 40% in stomatal density at high salinity ( $\Psi_o = -2.6$  MPa). Barbieri et al. (2012), in a study employing two basil (*Ocimum basilicum* L.) cultivars (Napoletano and Genovese) with different ability to respond to salt stress showed that reduced stomatal density, high ascorbate level and polyphenol oxidase activity coordinately contributed to improve adaptation of basil and Water Use Efficiency (WUE) in saline environment. The constitutively reduced stomatal density was associated with a “delayed” accumulation of stress molecules (and growth inhibiting signals) such as ABA and proline, in the more tolerant basil cultivar (Genovese).

#### The thickness of epidermis and cortex

Anova results showed that concentration of NaCl significantly affected the average thicknesses of root epidermis and cortex ( $P < 0.05$ ), but galangal species and the interaction of galangal species by NaCl concentration caused no significant effect ( $P > 0.05$ ) on the observed variables. Mean epidermis and cortex thicknesses of galangal root at different NaCl concentration treatments are presented in Table 4.

Table 4 shows that the average thickness of root epidermis increased significantly with an increase in NaCl concentration. The galangal plants treated with NaCl concentration of 12‰ resulted in the highest average epidermis thickness (19.67  $\mu\text{m}$ ). The average thickness of the root epidermis at the NaCl concentrations of 3‰ and 6‰ did not differ significantly from the control treatment. This indicated that the galangal plant was able to adapt well to salinity stress conditions of up to 6‰ NaCl. The increase in epidermal cells is an attempt to reduce the entry of excess salt and protect the underlying tissue (Turan et al. 2009). The thickness of the root epidermis will increase in species that are tolerant to high salinity condition because the thickness of the epidermis is a special character exhibited by tolerant species (Awasthi and Pathak 1999).

In contrast to root epidermis, the average thickness of root cortex decreased significantly along with the increase of NaCl concentration. The highest decrease in thickness of root cortex (17.83  $\mu\text{m}$ ) was observed at NaCl concentration of 12‰ (Table 4). The decrease in cortex thickness is the root response of plants against salinity stress. Salinity can cause changes in the cell structure of plant roots such as increasing the thickness of the epidermis as a way to reduce the increased salt exposure and the decrease in cortex thickness as the effect of the reduced food supply so that

the turgidity of cells in the cortex is decreased. Ceccoli et al. (2011) also reported that the root diameter of the *Chloris gayana* Kunth did decrease with increased salinity. This indicates that the thickness of the root cortex also decreases as salinity increases. Reduction of the cortex thickness due to salt stress was also found in other plants such as soybean (Dolatabadian et al. 2011) and *Gazania harlequin* (Younis et al. 2014).

#### Chlorophyll content

Each of the single factors of galangal species and NaCl concentration significantly affected chlorophyll content ( $P < 0.05$ ), but the interaction of these two factors had no significant effect ( $P > 0.05$ ) on the observed variable. Chlorophyll content of galangal plant under different galangal species and NaCl concentration are presented in Table 2.

Table 2 shows that the chlorophyll content of red galangal (20.40 CCI) was significantly higher than that of white galangal (16.90 CCI). The difference in chlorophyll content of the two galangal species might have been due to variations in individual genes controlling the trait. Gardner et al. (2003) stated that the growth and crop yield are influenced by internal factors such as the genetic trait, i.e., an inherited specific element owned by the plant itself. The average chlorophyll content was observed decrease with the increase of NaCl concentration. The lowest average chlorophyll content (8.93 CCI) was observed at the NaCl concentration treatment of 12‰. The NaCl treatment of 6‰ produced an average chlorophyll content that was similar to that of either control (0‰ NaCl) or 3‰ NaCl treatment but was significantly different from that of 9‰ and 12‰ NaCl treatments. This showed that the galangal plant was able to tolerate a salinity condition of up to 6‰ NaCl for chlorophyll content trait.

Table 2 indicates a decrease in chlorophyll content due to NaCl treatment. This decrease of chlorophyll levels may be due to increased degradation and synthesis inhibition of chlorophyll pigment (Stepien and Klobus 2006). The previous study by Zhao et al. (2007) revealed that the effect of salinity on chlorophyll content could lead to inhibition of chlorophyll synthesis and thus the chlorophyll content will decrease. The chlorophyll biosynthesis barriers may be due to the accumulation of the salts (Ali et al. 2004). Na accumulation has an adverse effect on Mg and Ca contents in leaves because Na will inhibit Mg and Ca absorptions. The decrease of Ca content in leaf increases the permeability of the membrane to salt, while Mg deficiency will cause inhibition of chlorophyll biosynthesis (Delfine et al. 1998), particularly in the pre-protchlorophyll stage in the chlorophyll biosynthesis pathway (Chen et al. 1998). Disturbance of chlorophyll formation also occurs in plants that have decreased total nitrogen uptake as a critical element in chlorophyll formation along with increased salinity (Pessarakli 1994). Similar results were also reported by Mahboobeh and Akbar (2013), where the total chlorophyll content of *Nicotiana plumbaginifolia* leaves decreased with the increase of NaCl concentration. The decrease in chlorophyll content with increased soil salinity was also reported by Jaleel et al. (2008).

**Table 1.** Average plant height increase of galangal at different NaCl concentration at 24 days after treatment

NaCl concentration	Plant height increase (cm)
0‰	1.67 c
3‰	1.17 c
6‰	0.83 ab
9‰	0.50 ab
12‰	0.17 a

Note: Means followed by the same letter are not significantly different at 5% DMRT

**Table 2.** Average leaf area and chlorophyll content of galangal plants under single factor treatments; the galangal species and levels of NaCl concentration

Treatments	Average leaf area (cm <sup>2</sup> )	Chlorophyll content (CCI)
<b>Galangal species</b>		
<i>A. purpurata</i> (red galangal)	40.60 a	20.40 b
<i>A. galanga</i> (white galangal)	56.90 b	16.90 a
<b>NaCl concentrations</b>		
0‰	54.23 b	24.15 c
3‰	52.98 b	22.55 c
6‰	51.62 b	21.05 c
9‰	44.32 a	16.57 b
12‰	40.58 a	8.93 a

Note: Means followed by the same letter in the same treatment group are not significantly different at the 5% DMRT

**Table 3.** Average dry weight (g) of galangal under galangal species by NaCl concentration interaction effect

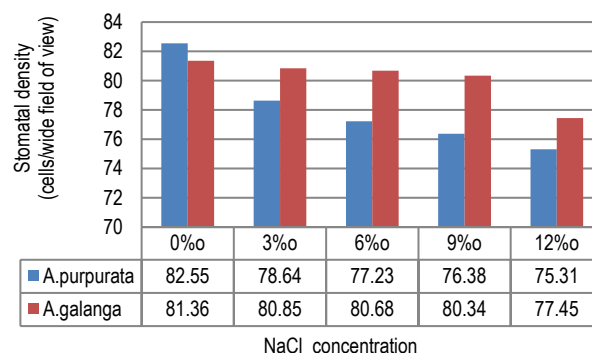
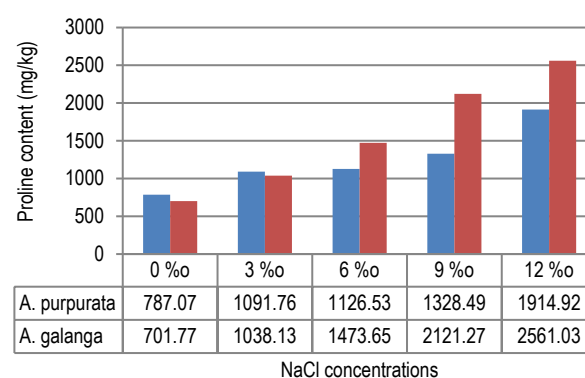
Galangal species	NaCl concentration				
	0‰	3‰	6‰	9‰	12‰
Red galangal	4.83 bc	4.76 ab	4.65 a	5.76 d	4.57 a
White galangal	6.22 ef	5.91 de	6.22 ef	5.38 c	5.04 b

Note: Means followed by the same letter are not significantly different at the 5% level by DMRT

**Table 4.** Average epidermis and cortex thicknesses of galangal root at different NaCl concentration

NaCl concentration	Average epidermis thickness (μm)	Average cortex thickness (μm)
0‰	17.17 a	29.50 d
3‰	17.33 a	22.83 c
6‰	17.83 a	20.67 bc
9‰	18.83 b	18.67 ab
12‰	19.67 b	17.83 a

Note: Means followed by the same letter are not significantly different at the 5% level by DMRT

**Figure 1.** The average stomatal density of galangal at different concentration of NaCl**Figure 2.** Average proline content of galangal on the different NaCl concentrations

### Proline content

Proline content of leaves of red galangal and white galangal at different concentrations of NaCl can be seen in Figure 2. Figure 2 shows that the average proline content did increase along with the increasing salinity level. The highest proline content of red galangal and white galangal were 1914.92 mg kg<sup>-1</sup> and 2561.03 mg kg<sup>-1</sup>, respectively, or increased by 143.61% and 264.93%, respectively. This result was similar to that reported by Farhoudi et al. (2015) that the treatment of NaCl watering with levels of 0.6, 4 and 8 dS m<sup>-1</sup> in some *rapeseed* cultivars increased proline content as NaCl levels increased.

Proline is the dominant organic molecule acting as an osmotic mediator during saline conditions, a balancer of cellular structures, energy reserves, and signal related to plant stress (Benhassaini et al. 2012), osmoprotectants under stress conditions, and serve to maintain membrane structure and acting as free radical scavengers which prevents lipid peroxidation and K<sup>+</sup> channels regulator in stomata (Parida and Das 2005). High proline content is known to protect various enzyme systems against dehydration process (Fagbola et al. 2001). Under saline stress, the stress-resistant genotypes accumulated proline at a higher level than the stress-sensitive one (Soheilikhah et al. 2013).

**Table 5.** The tolerance level of eight observation parameters based on sensitivity index (SI) salinity stress

Parameter	<i>A. purpurata</i> (red galangal)		<i>A. galanga</i> (white galangal)	
	Sensitivity Index	Category	Sensitivity Index	Category
Plant height increase	0.833	Moderately tolerant	1.167	Sensitive
Leaf area	0.711	Moderately tolerant	1.195	Sensitive
Dry weight	0.453	Tolerant	1.424	Sensitive
Stomatal density	0.429	Tolerant	1.563	Sensitive
Epidermis thickness	1.717	Sensitive	0.507	Moderately tolerant
Cortex thickness	1.001	Sensitive	0.999	Moderately tolerant
Chlorophyll content	0.750	Moderately tolerant	1.260	Sensitive
Proline content	0.947	Moderately tolerant	1.039	Sensitive

**Table 6.** Scores of sensitivity level of galangal plants to salinity stress based on sensitivity index (SI)

Species	Sensitivity level									Total
	Tolerant			Moderately tolerant			Sensitive			
	Parameter	Value	Score	Parameter	Value	Score	Parameter	Value	Score	
Red galangal	2	2	4	4	1	4	2	0	0	8
White galangal	0	2	0	2	1	2	6	0	0	2

### Salinity stress susceptibility level of galangal plants

Salinity stress susceptibility level of the tested galangal species was determined by calculating sensitivity index (SI) based on the eight observed parameters (Tables 5 and 6). Table 5 shows that the red galangal was tolerant to salt stress on the parameters of dry weight and stomatal density and was sensitive to the parameters of epidermis and cortex thickness; meanwhile, the white galangal was sensitive to six parameters of eight observed parameters except for the epidermis and cortex thickness that showed a moderate tolerant phenotype. The most tolerant galangal species was determined by calculating the total score of each tolerance level as follows: tolerant = 2, moderately tolerant = 1 and sensitive = 0 (Syafi 2008) as presented in Table 6.

Based on the sensitivity level, the red galangal (*A. purpurata*) showed a higher total score (8) than white galangal (*A. galanga*) with the total score of 2 (Table 6). This indicated that the red galangal (*A. purpurata*) was more tolerant to NaCl salt stress than the white galangal (*A. galanga*). Differences of plant species can result in different adaptability and tolerance capabilities to environmental stresses such as salinity. Aini et al. (2012) suggested that plant responses to salinity stress differ in species or genotype.

The observation result is expected to be used as a reference for subsequent research that may be useful in saline land management efforts for the development of cultivation of the more salt stress tolerant red galangal as compared to the white galangal.

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