Physiological Aspects of the Growth of Corns (Bonanza 9-F1 and Bisi-18) to Air Salinity Conditions on Coastal Area

Saparso[1](✉), Arief Sudarmaji[2], and Muhammad Bachtiar Musthafa[1]

[1] Department of Agrotechnology, Faculty of Agriculture, Jenderal Soedirman Universitas, Purwokerto, Indonesia
saparso@unsoed.ac.id

[2] Department of Agricultural Technology, Faculty of Agriculture, Jenderal Soedirman Universitas, Purwokerto, Indonesia

Abstract. The air salinity in coastal area may contribute significant effects to the growth of plants. Physiological aspects of the plant growth of plants are important information to give optimal treatments during cultivation process. One potential plant cultivated on coastal area is corns. This study aimed to study the physiological response of corn's growth to certain air salinity condition during cultivation on coastal area, and to determine their salinity tolerance index. The research was conducted in a screen house at the experimental farm of the Faculty of Agriculture, Jenderal Soedirman University, from July to November 2021. The study was conducted using method of Randomized completely Block design factorial with two factors. The first factor is the corn varieties (Bonanza -9 F1 and Bisi-18), and the second factor is air salinity (0 mS, 6 mS, 12 mS, and 18 mS). The data were analyzed by using the Anova, and continue to 5% Duncan's Multiple Range Test (DMRT), when the result is significantly different. The observed variables were plant height, number of leaves, leaf area, root length, fresh root weight, root dry weight, stem fresh weight, dry stem weight, fresh leaf weight, dry leaf weight, and chlorophyll a and b, proline content, stomata density, widht stomata opening, fresh weight of corn cob, dry weight of corn cob, seed fresh weight, dry seed weight, and number of seeds. The results of the research showed that the tolerance index of the Bisi-18 corn was higher than Bonanza 9-F1 corn, which showing better physiology aspects of chlorophyll content and proline content. The 6 mS air salinity treatment reduced chlorophyll content at the end of vegetative and generative, leaf area, fresh and dry weight of seeds, and the number of corn seeds. The 18 mS air salinity treatment showed the highest proline content and decreased at 12 mS and 6 mS treatments. The interaction of treatments on proline content, stem fresh weight, and chlorophyll content showed that Bonanza 9-F1 corn plants with 18 mS air salinity treatment showed the highest yields. The tolerance level of the Bisi-18 corn showed that the plant was still tolerant at 18 mS salinity. In comparison, the Bonanza 9-F1 corn showed intolerant results at 6 mS air salinity.

Keywords: physiological aspects · air salinity · corn growth · coastal area

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1 Introduction

Corn is a food crop that replaces rice in several regions in Indonesia. Corn is divided into two types, namely sweet corn and common corn. The difference between sweet corn and common corn is that the hairs on sweet corn are white, while in common corn they are red, besides that the harvest age of sweet corn is shorter, namely 70–90 DAP [1], while common corn is 85–95 DAP [2]. The demand for corn has increased every year. The corn consumption in 2021 is 739,758 tons/year, in 2022 it is 858,149 tons/year, in 2023 it is 1,006,479 tons/year, and in 2024 it is 1,157,211 tons/year [3]. The increase in the national demand for corn must be balanced with higher corn productivity.

The problem faced in corn production is the availability of agricultural land that is getting narrower due to the conversion of agricultural land. Efforts that can be made are to carry out intensification in the form of using superior varieties of seeds, eradicating pests and diseases, and managing effective agricultural land [4]. Extensification of agricultural land is also an effort that can be done, one of which is using marginal coastal sand as agricultural land.

Coastal soil has a sandy texture, is easily eroded by wind and water, has low nutrient content, and changes in soil temperature which are the main obstacles in the process of cultivating food crops and horticulture. The yield of corn production will decrease along with the increase in salinity levels in the growing media [5]. Another problem for cultivation on coastal soil is strong sea winds and contains sea salt which can damage plant leaves [6].

Salinity in the growing media may cause the deficiencies in plants. The high Na content causes the plants to experience poisoning, resulting in damage to the permeable membrane of parenchyma cells [7]. Corn can survive in water salinity concentrations of up to 4000 ppm or the equivalent of 6.25 mS [8]. The stress experienced by plants that grow on coastal soil in addition to soil salinity is an unfavourable environmental condition for some types of plants. The wind that blows carries salt vapor which causes difficulties in choosing cultivated plants [9].

Salinity stress can cause a decrease in chlorophyll content in plant leaves because it increases the activity of the chlorophyllase enzyme caused by reduced absorption of Mg and Fe ions involved in the formation of chloroplasts [10]. The lower levels of chlorophyll in plants, the results of photosynthesis (assimilation) also decreased. Assimilate will be translocated to all parts of the plant for the process of growth and development [11].

The research aimed to obtain the growth response and yield of corn at various levels of air salinity cultivated on coastal soil, and to determine the air salinity tolerance index of corn cultivated on sandy land.

2 Methods

The research was conducted at the Greenhouse of the Faculty of Agriculture, Jenderal Sudirman University and the Laboratory of Agronomy and Horticulture, Faculty of Agriculture, Jenderal Soedirman University, Purwokerto, Banyumas, from July to November 2021.

The method used in this research is Randomized Completely Block Design with factorial pattern. The first factor was the corn variety (J1 = Bonanza 9-F1, and J2 =

Bisi-18). The second factor was the air salinity level (S0 = 0 mS salinity (control), S1 = 6 mS salinity, S2 = 12 mS salinity, S3 = 18 mS salinity). While the parameter observed of the plant physiologies are stomatal density, stomata aperture, and chlorophyll content were observed at vegetative and generative phase, while proline content was observed at generative phase.

2.1 Chlorophyll Content (μg/ml)

Leaf sample 0.1 g crushed in a mortar with 10 ml of 80% acetone. The extract in the cuvette was observed for absorbance values of chlorophyll solution at wavelengths of 663 nm and 645 nm using a spectrophotometer bates. Chlorophyll content was calculated using the formula (mg/L) = (20.2 × A645 nm) + (8.02 × A663 nm) [12].

2.2 Proline Content (μmol/g)

The proline content was determined in 0.5 g of plant leaves which were mash together with 10 ml of 3% sulfosalicylic acid solution. 2 ml of filtrate was reacted with 2 ml of ninhydrin acid and 2 ml of glacial acetic acid in a test tube and then boiled at 100 °C for 1 h. The mixture was extracted with 4 ml of toluene and then shaken with a stirrer for 15–20 s. The spectrophotometer calibration was carried out using pure toluene. The red toluene containing proline in the upper part is sucked up with a pipette. The absorbance of solution was read with a spectrophotometer at a wavelength of 520 nm.

2.3 Stomata Density (mm^2)

The underside of leaves was smeared with clear nail polish until dry and the nail polish was removed from the leaves using clear duct tape as a stomata print. The nail polish fluid that formed the stomata was placed on the slide and then observed under a microscope with a magnification of 40 times. After the stomata are visible, then the photo is taken and the stomata count is carried out.

2.4 Stomata Aperture (μm)

The stomata aperture (μm) was observed under a microscope with a magnification of 40 times. The stomata aperture was calculated using an ocular micrometres so that the stomatal aperture could be observed.

Tolerance index based on corn yield according to Nurhayati [13].

$$\text{STI} = (\text{Hp x Hs}) / (\text{H}\overline{\text{p}})^2$$

STI = Stress Tolerance Index.

Hp = Measurement results in unstressed conditions.

Hs = Measurement results in stressed conditions.

$\text{H}\overline{\text{p}}$ = The average yield of all genotypes under unstressed conditions.

the data were analysed using analysis of variance (ANOVA) If the results of the Anova was significantly different then continued with the DMRT 5% and a regression analysis.

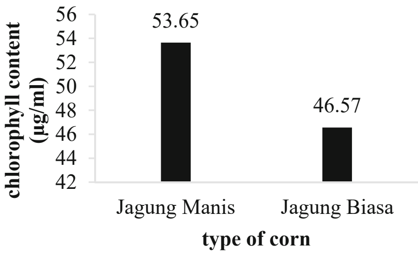

Fig. 1. Final generative chlorophyll content in type of corn.

3 Result and Discussion

The results of analysis of variance showed that the treatment of plant species had no effect on the final vegetative chlorophyll content, stomatal density, and stomata aperture, significantly affected the final generative chlorophyll content, and proline content. Salinity levels significantly affected the final vegetative chlorophyll content, generative final chlorophyll content, and proline content. Other variables showed results that were not significantly different. There is a highly significant interaction on the variable levels of final generative chlorophyll and proline content.

3.1 Chlorophyll Levels and Leaf Greenness of Two Corn Varieties at Various Air Salinities

Chlorophyll content at the final generative phase showed significantly different results in type of corn. The chlorophyll content in sweet corn plants is higher than common corn. The chlorophyll content of sweet corn was 53.65 mg/g, while that of regular corn was 46.57 g/ml.

Chlorophyll contents at final generative affect the yield of plant production because when entering the generative phase the plant begins to flower and the corncob begins to fill. The results of the analysis on the production of common corn are higher than sweet corn even though the chlorophyll content in sweet corn is higher. These results are thought to be due to different plant characteristics and different harvest times. Sweet corn was harvested at 88 DAP while common corn was harvested at 97 DAP. Chlorophyll is one of the factors that influence the process of photosynthesis [14]. In addition to leaf chlorophyll content, other variables that affect corn production are plant height and leaf area. Photosynthesis process requires sufficient sunlight, while sweet corn has higher chlorophyll content but lower plant height and leaf area than common corn so that the results of photosynthesis are not better than common corn in terms of plant production.

Based on the results of the analysis chlorophyll levels at final vegetative phase, the results showed very significant differences in the treatment of salinity levels (Fig. 1).

Meanwhile, in the treatment of plant species and interactions between treatments, the results were not significantly different. The results of the chlorophyll test at the vegetative end showed that the control treatment, namely air salinity levels of 0 mS, showed the highest chlorophyll content, which was 46.87 using a SPAD device and 48.54 mg/g using a spectrophotometer.

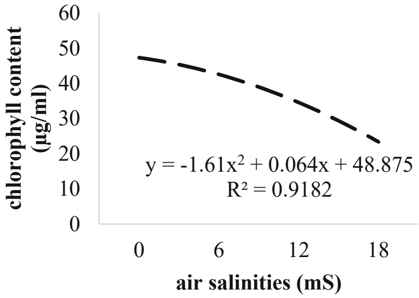

Fig. 2. Final vegetative chlorophyll content at various air salinities.

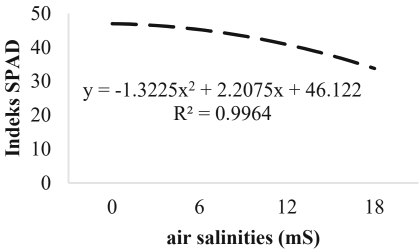

Fig. 3. Final vegetative SPAD index at various air salinities.

The lowest chlorophyll content was found in the 18 mS air salinity treatment, 33.93 using a SPAD device and 22.16 mg/g using a spectrophotometer. Leaves are plant parts where food synthesis occurs which is then used by plants to growth and development needs as well as food reserves. The process of photosynthesis in plants occurs in leaves that have chlorophyll, the high amount of chlorophyll in plant leaves can improve the quality and results of the photosynthesis process. This is in accordance with the opinion of Suhastyo and Raditya [15], which states that higher amount of chlorophyll and the number of plant leaves, the photosynthesis process will be better and more abundant. Chlorophyll levels in plant leaves can be influenced by internal and external factors. The treatment of different air salinity levels showed that the higher salinity level, the lower chlorophyll content in plant leaves. Decreasing levels of chlorophyll in the leaves will certainly affect the production of corn plants. The process of photosynthesis will be increasingly disturbed along with the increase in the level of salinity of the given air (Figs. 2 and 3).

The chlorophyll content at final generative showed very significant different results in the treatment of air salinity levels. The higher salinity of the given air, the lower chlorophyll content in plants. This result is consistent with the observation of chlorophyll content at final vegetative phase of the plant. Treatment of air salinity levels of 0 mS showed the highest salinity levels, 54.58 using SPAD and 64.79 g/ml using a spectrophotometer. Meanwhile, the lowest chlorophyll content was found in the 18 mS air salinity treatment, which was 34.03 in the measurement using SPAD and 36.75 g/ml using a spectrophotometer.

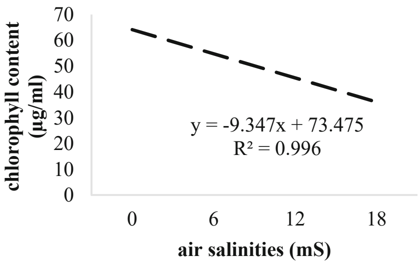

Fig. 4. Final generative chlorophyll content at various air salinities**.**

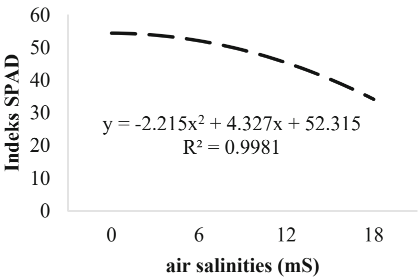

Fig. 5. Final generative SPAD index at various air salinities.

Chlorophyll levels in plant leaves have an influence on the photosynthesis process. The lower chlorophyll, the lower photosynthesis results [11]. Higher photosynthetic yields will increase plant production. The results of photosynthesis (assimilate) will be used by plants for the process of plant growth and development. The process of photosynthesis at end generative phase will focus more on the formation of corn seeds. The assimilate translocated to the vegetative part of the plant is not the same as the amount of assimilate that is translocated to the food storage area [16].

The results of leaf greenness analysis at final generative phase with the SPAD tool showed that there was an interaction between the two treatments that were very significantly different. The measurement of leaf greenness using the SPAD tool was highest in the combination of sweet corn treatment with air salinity levels of 0 mS, which was 56.47, while the lowest results were in the combination of sweet corn treatments with air salinity levels of 18 mS, which was 30.93. Leaf greenness of common corn leaves follows the equation $YJB = -1.5025x2 + 2.3755x + 51.738$, and sweet corn is $YJM = -2.9275x2 + 6.2805x + 52.883$. (Figs. 4 and 5).

There are differences in the results of leaf greenness with SPAD and spectrophotometer. The differences that occur are thought to be due to different leaf sampling and also the number of samples per plant that is different between tests with SPAD and spectrophotometers. Each leaf observed has different chlorophyll content, even leaves in the same individual plant. In accordance with the results of the analysis on the treatment of plant species and salinity levels, the higher salinity level given, the lower chlorophyll content in the plants. Salinity treatment to plants showed a significant effect on plant

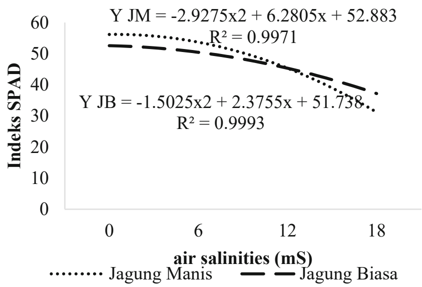

Fig. 6. Leaf greenness of two types corn at various air salinities.

chlorophyll levels. The results of analysis on the treatment of plant species also showed that common corn was more tolerant of air salinity stress. The results of analysis on the treatment of sweet corn with salinity levels of 18 mS had the lowest chlorophyll content because sweet corn was more sensitive to air salinity treatment and the higher salinity level, the lower chlorophyll content.

Chlorophyll levels are certainly strongly influenced by the level of salinity of the air. In the treatment of plant species, the chlorophyll content of sweet corn was relatively higher than that of common corn. The administration of air salinity stress treatment resulted in the chlorophyll content of sweet corn decreased faster than common corn. This effect is in accordance with the growth variable which shows that common corn are more tolerant of air salinity stress. The decrease in chlorophyll levels in plants is in line with the increase in salt levels which is usually characterized by the presence of chlorosis in the leaves [17] (Fig. 6).

3.2 Proline Content of Corn at Various Air Salinities

The results of proline content analysis in corn showed significantly different results in the treatment of plant species and very significant differences in the treatment of air salinity levels. The proline content in common corn showed a higher yield of 2.68 mol/g than in sweet corn at 2.16 mol/g. The higher proline content in plants makes plants have a good tolerance to air salinity stress. The air salinity treatment showed the highest proline level in the 18 mS air salinity treatment, which was 3.58 mol/g and the lowest proline level in the 0 mS air salinity treatment, which was 1.75 mol/g. The higher the level of air salinity given, the proline content in the plant also increases.

The proline content in common corn has a greater yield due to the characteristics of common corn which are more tolerant of salinity stress. This is in accordance with Restanancy [18] statement which states that the Bisi corn variety has resistance to salinity stress in saline watering treatment. The growth and development of plants under stress of air salinity is strongly influenced by the genetics of each plant variety tested. This is in accordance with the opinion [19] which states that the proline content in plants is an indicator of plant resistance to stress, the tolerance ability of each plant varies, resulting in diverse proline content due to differences in the nature and genetics of each plant variety.

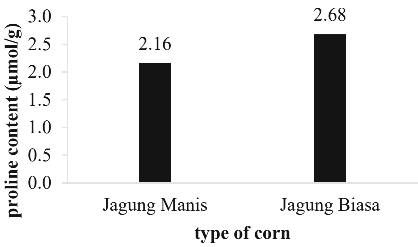

Fig. 7. Proline content in the type of corn.

Plants that are tolerant to salinity stress have higher proline accumulation than plants that are sensitive to salinity. The content of proline in plants can help plant metabolism as a source of cytoplasmic osmoticum as well as protect cellular structures in corn plants which can help plants cope with environmental stresses of growth [20]. The higher amount of proline content in ordinary corn indicates that the metabolism of common corn under air salinity stress is better than that of sweet corn.

The proline content in corn showed an interaction between the treatment of plant species and air salinity levels. The interactions that occur are very different. The highest proline content was found in sweet corn treatment with air salinity level of 18 mS, which was 3.89 mol/g, while the lowest proline content was found in sweet corn treatment with 0 mS air salinity or control, which was 0.6 mol/g. Equation for calculating proline content in ordinary corn is $YJB = 0.415x2 - 1.953x + 4.45$, while in sweet corn it is $YJM = 0.09x2 + 0.534x + 0.145$ (Fig. 7).

Based on the results of proline content analysis in the treatment of plant species and air salinity levels, it shows that the higher salinity level, the higher proline content will also be. Sweet corn plants which were more sensitive to salinity showed the highest proline yield in the 18 mS salinity treatment compared to other treatments. The increase in proline levels along with the increase in salinity levels occurred in both types of plants used. This is in accordance with the statement of Sobir [21] which states that the proline content in plants increases with increasing salinity levels, genotypes that are more sensitive to salinity will produce higher prolines when compared to tolerant genotypes.

Proline content is a response shown by plants as a plant response to adapt to a given salinity stress condition to reduce the occurrence of plant cell damage [22]. Increased levels of salinity can cause plants to lose water due to the osmotic pressure that occurs, plants with low water content can interfere with plant metabolism so that it affects plant growth and yields. The increase in proline content in plants is a result of biosynthesis of organic compounds with the aim of overcoming osmotic pressure as a plant response to saline stress [23] (Fig. 8 and Tables 1 and 2).

3.3 Air Salinity Tolerance Index

Plant tolerance to air salinity stress is the ability of plants under stress conditions to grow and give high yields under air salinity stress conditions. One of the methods used

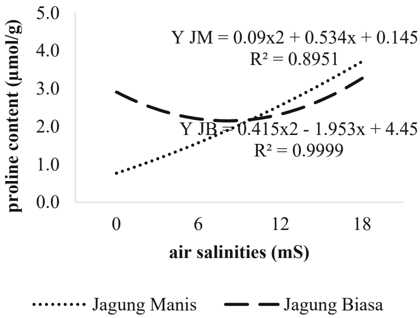

Fig. 8. Proline content of two types of corn at various air salinities.

Table 1. Air salinity stress tolerance index level 18 mS

No	Variable	STI	
		Bonanza 9-F1	Bisi-18
1.	Fresh Weight of Seeds	0,23 tt	1,45 t
2.	Number of Seeds Per Cob	0,26 tt	1,08 t

Table 2. Air salinity stress tolerance index level 6 mS

No	Variable	STI	
		Bonanza 9-F1	Bisi-18
1.	Fresh Weight of Seeds	0,3 tt	1,77 t
2.	Number of Seeds Per Cob	0,35 tt	1,61 t

Description: STI = Stress Tolerance Index; STI $<$ 0.5 plants were sensitive (tt); 0.5 STI 1 plant is medium tolerant (mt); STI $>$ 1 plant is tolerant (t).

to determine the tolerance of plantss to salinity stress is the STI (Stress Tolerance Index) formula.

The common corn (Bisi-18) is tolerant of air salinity stress up to 18 mS, while sweet corn (Bonanza 9-F1) has shown intolerant results at 6 mS air salinity. The calculation of the tolerance index on the fresh weight of seeds and the number of seeds per cob showed that ordinary corn plants were tolerant of air salinity.

4 Conclusion

1. The chlorophyll content at 0 mS air salinity is 64.79 mg/g decreases with increasing air salinity to 36.75 g/ml at 18 mS air salinity. The leaf greenness of corn follows the equation YJB = -1.5025x2 + 2.3755x + 51.738, and sweetcorn is YJM = -2.9275x2 + 6.2805x + 52.883.

2. The proline content of corn Bisi 18 was higher (2.68 mol/g) than Bonanza 9-F1 corn (2.16 mol/g). The proline content increased with increasing air salinity 0 mS (1.75 mol/g) air salinity 18 mS (3.58 mol/g). The proline content in common corn followed YJB = 0.415x2 - 1.953x + 4.45, while in sweet corn it was YJM = 0.09x2 + 0.534x + 0.145.
3. The Bisi-8 corn is tolerant to air salinity up to 18 mS and the Bonanza 9-F1 corn is not tolerant even at 6 mS.

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