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Assessing the air salinity on agro-physiological response of *Brassica oleracea* var. *capitata* and *Brassica oleracea* var. *botrytis*

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Abstract
Air salinity is one of the problems for horticulture production in coastal areas. Cabbage and Cauliflower are horticulture commodities that have the potential to develop in coastal areas. The present study aimed to examine the agro-physiological response of cabbage (*Brassica oleracea* var. *capitata*) and cauliflower (*B. oleracea* var. *botrytis*) to different concentrations of air salinity. This research was a factorial experiment on polybags arranged according to a completely randomized block design with two factors. The first factor was the crop type, namely cabbage (Grand 22) and cauliflower (Larissa F1). The second factor was the concentration of air salinity, namely 0 dS. m^{-1}, 6 dS. m^{-1}, 12 dS. m^{-1}, and 18 dS. m^{-1}. The agro-physiological changes studied were crop yield, leaf chlorophyll content, stomata density, and proline content. A stress tolerance index was measured to determine the level of crop resistance to air salinity stress. The results explained that air salinity was not able to affect crop growth and yield, but it enabled to affect crops physiologically. The highest decrease in leaf chlorophyll content was at 18 dS. m^{-1} of 29.16% in the vegetative stage and 37.88% in the generative stage. There was an increase in proline accumulation of leaf (1,320.63%) when the air salinity was increased (18 dS. m^{-1}). However, the accumulation of cabbage proline was lower than that of cauliflower. Based on the stress tolerance index, cabbage is included in the category of tolerant, while cauliflower is in the category of moderate tolerance to air salinity.

Keywords: Air salinity, Cabbage, Coastal area, Cauliflower, Stress tolerance index, vegetable

INTRODUCTION

Horticultural crops provide most of the nutrients necessary for human nutrition, such as carbohydrates, minerals, micronutrients, proteins, vitamins, lipids, fibre, organic acids, pigments, and antioxidants (Imahori, 2014). Horticulture crops are crucial for a balanced diet, a significant source of income, and a means of eradicating poverty for farmers in underdeveloped nations (Hayashi *et al.,* 2010). These crops can provide the economy and agricultural variety of developing nations with energy. The demand for vegetables is expected to increase significantly because of ongoing growth in the standard of living and a desire for nutrient-dense meals (Ruel, 2018). Horticultural commodities have considerable potential since they have high economic value and many possibilities to develop added value compared to other commodities. Many different horticulture products have been developed in Indonesia; 33 provinces produce more than 20 varieties of vegetables. Nevertheless, of the 20 varieties, Java and Sumatra produce the most, up to 85%. West Java (35.6%), Central Java (13.3%), East Java (11.9%), and North Sumatra (10.3%) are the provinces that produce the most vegetables, accounting for more than 70% of all vegetables produced in Indonesia (Central Statistical Agency, 2021).

Two horticultural products, especially *Brassica oleracea* var. *capitata* (cabbage) and *Brassica oleracea* var. *botrytis* (cauliflower), are still being developed be-

cause of their potential for high export values. According to the Central Statistical Agency (2021), 1.43 million tonnes of cabbage were produced in 2021, with annual fluctuations in production. Compared to the previous year, when there were 1.41 million tons, this amount climbed by 1.97%. Every year, the amount of cauliflower produced tends to vary, with output in 2021 being 203.385 tons. Compared to the previous year, which saw a total of 204.385 tons, this number fell by 0.42%. Due to continuity and quantity issues, export competitiveness globally decreases with variable production levels. The increasingly constrained agricultural land for cabbage and cauliflower in Indonesia is one of the causes contributing to their low competitiveness (Servina, 2019; Nugroho, 2021). This is supported by Asian Development Bank (2015) that Indonesia's agricultural land ownership structure is extraordinarily skewed and unequal. Only 68% of farmers have less than one hectare. Using less-than-ideal land to develop horticultural crops is necessary to boost the output of horticultural commodities in a sustainable way.

Coastal sandy land is a less desirable type of dry land because it is generally marginal land. Considering that Indonesia is an archipelago with 60% of its land covered by water, the coastal sandy land there potentially supports the cultivation of horticultural crops, namely cabbage and cauliflower (Saparso *et al.,* 2009; Putra *et al.,* 2017; Faozi *et al.,* 2021). Several problems arise when growing cabbage and cauliflower plants on Coastal sandy land. High light levels, strong winds, salinity, sandy soil, and low fertility are problems in coastal sandy land (Athulya *et al.*, 2023; Ukaegbu and Nnawuihe, 2020). Coastal sand soil contains deficient levels of nitrogen (26.79 ppm), soil organic matter (0.07 -1.17%), and COC (1.16-10.21 cmol (+) kg^{-1}) (Saparso *et al.,* 2003; Athulya *et al.*, 2023). Sea salt particles carried by the wind from the sea can hinder plant growth. The salinization process in coastal sandy soils exacerbates some of the abovementioned issues.

Moreover, it causes various physiological and biochemical functions, including nutrient and water intake, to become disrupted (Hnilickova *et al.,* 2021; Barus *et al.,* 2021). According to Anshori *et al.* (2018), salinity has three effects on plant growth and yield: osmotic, ion imbalance, and ionic stress. The production of biomass, the rate of photosynthesis, and the rate of transpiration were all shown to be reduced in crops grown under saline conditions (Giuffrida *et al.,* 2016; Radanielson, 2017). High salt levels can impact several variables, including plant height, dry weight, leaf damage, and crop yields (Ghosh *et al.,* 2016; Nasrudin and Kurniasih, 2021).

According to Devi and Arumugam (2019), cabbage and cauliflower are horticultural species that have moderate tolerance to salinity, despite salinity restrictions in the air and salinization in the soil preventing the development of cabbage and cauliflower in coastal lands. Hence, land extension in coastal areas still has the potential to improve the output of cabbage and cauliflower. There is research at the time on the effect of salinity on horticultural crop yields, but all of them just looked at the salinity of the soil; they did not look at the effect of air salinity. Based on the above fact, a study is needed on the influence of air salinity on horticultural crops, notably cabbage and cauliflower. So, the present study aimed to investigate the agro-physiological response of cabbage and cauliflower at various air salinity levels.

MATERIALS AND METHODS

Study area

The research was carried out from July to December 2021 in the greenhouse and the Agronomy and Horticulture Laboratory, Faculty of Agriculture, Jenderal Soedirman University, Purwokerto (7°24'27.7"S 109° 15'19.1"E). The temperature in the greenhouse during the research was in the range of 20.90°C - 38.25°C, while the air humidity in the greenhouse during the research was in the range of 29% - 99%.

Procedures

This research was a factorial arranged based on a Completely Randomized Block Design with two factors. The first factor was the type of plant (A1 = Cabbage (Grand 22), A2 = Cauliflower (Larissa F1)) and the second factor was air salinity (S0 = 0 dS. m^{-1}, S1 = 6 dS. m^{-1}, S2 = 12 dS. m^{-1}, and S3 = 18 dS. m^{-1}). The combination of treatment factors resulted in 8 treatment combinations carried out in 3 repetitions so that there were 24 experimental units, and each unit consisted of 5 polybags with a total of 120 polybags. The composition of the eight treatment combinations was as follows:

A1S0 = Cabbage with air salinity concentration of 0 dS. m^{-1};

A1S1 = Cabbage with air salinity concentration of 6 dS. m^{-1};

A1S2 = Cabbage with air salinity concentration of 12 dS. m^{-1};

A1S3 = Cabbage with air salinity concentration of 18 dS. m^{-1};

A2S0 = Cauliflower with air salinity concentration of 0 dS. m^{-1};

A2S1 = Cauliflower with air salinity concentration of 6 dS. m^{-1};

A2S2 = Cauliflower with air salinity concentration of 12 dS. m^{-1};

A2S3 = Cauliflower with air salinity concentration of 18 dS. m^{-1};

Agronomic variables

Using a measuring instrument, plant height (cm) was measured from the ground surface to the tallest shoot.

Leaf area (cm^2) was measured by arranging the leaves under the camera using a leaf area meter, then grabbed and measured in the winDIAS 3 versions 3.2.1 application. Determination of estimated crop yields uses a formula in which the results of weighing the entire crop were calculated and then converted to tons using the following formula:

Crop yield (t. ha^{-1}) = ((Fresh Weight of Crop)/(Planting distance))/(1.000.000 tonnes) x 10.000 m^2 ….. (1)

Determination of greenness leaf

The greenness value of the leaves of cabbage and cauliflower was read twice at the late vegetative and late generative stages. The value of the greenness of leaves was read based on the SP3 method of leaves with the help of a chlorophyll meter SPAD-502 plus. Collecting and retrieving data on chlorophyll content in leaves were randomly collected. The greenness value of the leaves obtained from each leaf sample reading was then taken as an average value. The average value of the SPAD-502 plus chlorophyll meter reading was used as the sample data to be processed. Measurements were taken when the weather was relatively clear to avoid interference (noise) in the data.

Determination of chlorophyll content

Determination of the concentration of chlorophyll levels was carried out based on the International Rice Research Institute (IRRI) method, which has been modified (Alsuhendra, 2004). Leaves of cabbage and cauliflower were weighed as much as 0.01 gram using a balance, then put into a mortar and then mashed with the addition of 80% acetone as much as 10 ml. Leaves of cabbage and cauliflower have been refined and filtered through filter paper. The extract obtained was analyzed for its chlorophyll concentration using a spectrophotometer with 645 and 663 nm wavelength. The chlorophyll content was calculated using the formula:

Chlorophyll Content (mg. L^{-1}) = (20.2 x A645) + (8.02 x A663) …..(2)

note:

A645 = Absorbance data at a wavelength of 645 nm

A663 = Absorbance data at a wavelength of 663 nm

Determination of proline content

The Bates *et al.* (1973) technique was used to assess the proline content (µmol g^{-1} fresh leaves). Crushed fresh leaves weighing 0.5 g were combined with 10 mL of sulfosalicylic acid, 3%, and filtered. The filtrate was combined with 2 mL of glacial acetic acid and 2 mL of ninhydrin, then placed in a tube and heated to 100 ^oC for an hour. The solution was extracted with 4 mL of toluene until it turned crimson. When measured with a 2D Milton Roy Spectrophotometer at 520 nm wavelength and calculated using the formula, the red color indicated the presence of proline in the solution at the top layer:

Proline content (µmol. g^{-1} FW) = (64.3649 x absorbance reading) + (-5.2987 x 0.347) …..(3)

Determination of stress tolerance index (STI)

The tolerance index is obtained by calculating the yield of cabbage and cauliflower at a certain level of air salinity compared to the yield of crops under normal conditions or in the control treatment. The calculation was based on the variable crop yield observations: crop diameter, crop formation age, and crop yield. The calculation was done using the formula according to Hooshmandi (2019).

$STI = (Hp \times Hs) / (H\overline{p})^2$.….(4)

note:

STI = Stress Tolerance Index

Hp = Crop yields in unstressed conditions

Hs = Crop yields under stress conditions

$H\overline{p}$ = Average yield of all genotypes under non-stress conditions

Data analysis

The data were analyzed using Analysis of variance (ANOVA). Duncan's Multiple Range Test continued at 5% if the data significantly differed between treatments. Statistical data processing was done using the Statistical Tools for Agricultural Research ver 2.0.1 and Microsoft Excel.

RESULTS

Based on the analysis of variance (Table 1), the present study showed no interaction between the treatment of cabbage (A1) and cauliflower (A2) and air salinity (S) in all observed variables. In a single treatment, crops species affected plant height, leaf area, leaf greenness in the vegetative stage, leaf greenness in the generative stage, chlorophyll content in the generative stage, stomatal density in the generative stage, proline content, and crop yield. In a single treatment, air salinity affected leaf greenness in the vegetative stage, leaf greenness in the generative stage, chlorophyll content in the vegetative stage, chlorophyll content in the generative stage, stomatal density in generative stage, and proline content.

Plant height

The plant height of cabbage (A1) and cauliflower (A2) showed significant differences (Table 2). In this research, Cauliflower (A2) plant height in this research was 43.60 cm or 33.05% higher than the cabbage (A2). However, the stress of the air salinity concentration is 0 – 18 dS. m^{-1} had no impact on plant height.

Leaf area

The leaf area of the cabbage (A1) and cauliflower (A2)

Table 1. Showing the result of a Two-way Analysis of Variance of the crop type, the air salinity, and their interaction with the variable.

Variable	Crops type (A)	Air salinity (S)	Crops type (A) x air salinity (S)
Plant height	56.52**	0.47^{ns}	0.15^{ns}
Leaf area	36.97**	0.86^{ns}	1.02^{ns}
Crop dry weight	0.52^{ns}	2.05^{ns}	1.10^{ns}
Leaf greenness in the vegetative stage	19.23**	24.68**	0.56^{ns}
Leaf greenness in the generative stage	18.67**	14.39**	0.68^{ns}
Chlorophyll content in the vegetative stage	1.67^{ns}	9.61**	0.15^{ns}
Chlorophyll content in the generative stage	8.44*	5.62**	0.42^{ns}
Stomatal density in the vegetative stage	0.58^{ns}	1.78^{ns}	0.54^{ns}
Stomatal density in the generative stage	6.81*	3.82*	0.30^{ns}
Proline content	12.53**	33.13**	0.41^{ns}
Crop Yield	27.77**	0.29^{ns}	1.36^{ns}

$^{*}P < 0.05$; $^{**}P < 0.01$; ns: not significant.

has a significant difference (Table 2). The leaf area of the cauliflower (A2) was 5,715.54 cm^2 or 28.13% narrower than cabbage (A1). Although cauliflower (A2) had a higher plant height, the leaf area of Cauliflower (A2) is narrower, which is influenced by the shape and structure of the leaves of the two crops. Then stress the air salinity at a concentration of 0 – 18 dS. m^{-1} (S0 – S3) given to crops has not had an impact on the growth of leaf area.

Crop dry weight

There was no difference in crop dry weight between cabbage (A1) and cauliflower (A2) (Table 2). Thus, the dry weight of cabbage (A1) and cauliflower (A2) was not affected by air salinity stress given at a 0 – 18 dS. m^{-1} (S0 – S3) concentration.

Leaf greenness (SPAD)

The leaf greenness of cauliflower (A2) was lower than cabbage (A1) in the vegetative and generative stages (Table 3). Leaf greenness on cauliflower (A2) was 9.26% lower in the vegetative stage and 8.93% in the generative stage. Leaf greenness of cauliflower (A2) and cabbage (A1) exposed to air salinity decreased with increasing air salinity concentrations up to 18 dS. m^{-1} (S3). The decrease in leaf greenness was 3.07%, 17.07%, and 22.23% in the vegetative stage and 7.17%, 14.33%, and 18.37% in the generative stage, with an air salinity concentration of 6 dS. m^{-1} (S1), 12 dS. m^{-1} (S2), and 18 dS. m^{-1} (S3).

Cholorophyll content

Chlorophyll content in cauliflower (A2) and cabbage (A1) was no different. However, the chlorophyll content in cauliflower (A2) was lower than cabbage (A1) in the generative stage (Table 3). The chlorophyll content in cauliflower (A2) was 19.46% lower than that of cabbage (A1). When given air salinity with several concentrations, the chlorophyll content decreased in the vegetative and generative stages. When not exposed to air salinity (S0), leaf chlorophyll content was detected at 23.12 mg. L^{-1} in the vegetative stage and 19.00 mg. L^{-1} in the generative stage. When crops were in the vegetative phase and exposed to air salinity with a concentration of 18 dS. m^{-1} (S3) caused leaf chlorophyll content to decrease by 29.16%. The exposure to air salinity with a concentration of 18 dS. m^{-1} (S3) in the generative phase caused a higher decrease in leaf chlorophyll content, namely 37.88%.

Stomatal density

Stomata density on cabbage (A1) and cauliflower (A2) was not different in the vegetative stage, and plant stomata density was not different in the air salinity treatment (Table 4). However, when the crop entered the generative stage, the density of cauliflower (A2) stomata became less than that of cabbage (A1). Cabbage (A1) showed increased stomata density from the vegetative to the generative stage of 6.14%. Meanwhile, the density of stomata in cauliflower (A2) decreased in the vegetative to the generative stage by 27.36%. Stomatal density also decreased when treated with different levels of air salinity. Stomatal density when the crops were not experiencing air salinity stress (S0) was 67.44 stomatal. mm^{-2}, then there was a decrease in stomatal density of 16.19% when the crops were exposed to air salinity with a concentration of 18 dS. m^{-1} (S3).

Proline content

The proline content in cauliflower (A2) was higher than in cabbage (A1) (Table 4). The proline content in cauliflower (A2) was 5.43 µmol g^{-1} FW i.e. 131.06% higher

Table 2. Air salinity effect on plant height, leaf area, and crop dry weight in cabbage and cauliflower

Treatment	Plant height (cm)	Leaf area (cm^2)	Crop dry Weight (g. $crop^{-1}$)
Crops type (A)			
Cabbage (A1)	33.27 b	7,965.61 a	100.82
Cauliflower (A2)	43.60 a	5,715.54 b	96.74
Air salinity (S)			
0 dS. m^{-1} (S0)	38.70	6,972.78	109.70
6 dS. m^{-1} (S1)	39.43	6,635.62	90.45
12 dS. m^{-1} (S2)	37.18	7,257.94	95.73
18 dS. m^{-1} (S3)	38.44	6,495.96	99.25
A x S			
A1S0	34.06	8,491.92	117.26
A1S1	34.06	7,670.85	92.89
A1S2	32.34	8,553.94	100.19
A1S3	32.61	7,145.72	92.96
A2S0	43.33	5,453.64	102.13
A2S1	44.81	5,600.39	88.00
A2S2	42.01	5,961.94	91.28
A2S3	44.26	5,846.20	105.53

Numbers in the same column followed by the same letter are not significantly different in Duncan's Multiple Range Test at a significant level of 5%

Table 3. Air salinity effect on leaf greenness and chlorophyll content under different growth stages in cabbage and cauliflower

Treatment	Leaf greenness (SPAD)		Chlorophyll content (mg. L^{-1})	
	Vegetative Stage	Generative Stage	Vegetative Stage	Generative Stage
Crops type (A)				
Cabbage (A1)	51.84 a	51.36 a	20.91	18.60 a
Cauliflower (A2)	47.42 b	47.15 b	19.98	15.57 b
Air salinity (S)				
0 dS. m^{-1} (S0)	54.65 a	53.94 a	23.12 a	19.00 a
6 dS. m^{-1} (S1)	53.02 b	50.33 b	21.19 b	18.96 a
12 dS. m^{-1} (S2)	46.68 c	47.18 c	19.55 c	16.58 b
18 dS. m^{-1} (S3)	44.18 d	45.57 d	17.90 d	13.78 c
A x S				
A1S0	57.68	56.94	23.47	19.87
A1S1	55.67	52.68	22.00	20.51
A1S2	48.42	49.17	20.10	19.03
A1S3	45.59	46.64	18.06	14.99
A2S0	51.62	50.93	22.77	18.14
A2S1	50.37	47.98	20.40	17.42
A2S2	44.93	45.19	19.00	14.14
A2S3	42.77	44.49	17.74	12.57

Numbers in the same column followed by the same letter are not significantly different in Duncan's Multiple Range Test at a significant level of 5%

than in cabbage. The crops treated with air salinity levels showed a response to increased levels of proline. The air salinity had a proline level of 0.63 µmol g^{-1} FW in the crops that were not given stress (S0). However, when the air salinity concentration was increased to 18 dS. m^{-1} (S3), the proline level in crops also increased 14 times, namely 8.95 µmol g^{-1} FW.

Crop yield

Cauliflower (A2) yields were lower compared to cabbage (A1). The cauliflower (A2) yield per hectare was 10.14 t. ha^{-1} and 31.11% lower than the cabbage (A1) yield (Table 5). However, unlike the physiological response, crops treated with air salinity levels did not impact crop yields. Air salinity level 0 – 18 dS. m^{-1} (S0 –

Table 4. Air salinity effect on stomatal density and proline content in cabbage and cauliflower

Treatment	Stomatal density (stomatal. mm^{-2})		Proline content (µmol g^{-1} FW)
	Vegetative Stage	Generative Stage	
Crops type (A)			
Cabbage (A1)	57.48	61.01 a	2.35 b
Cauliflower (A2)	66.31	48.17 b	5.43 a
Air salinity (S)			
0 dS. m^{-1} (S0)	65.51	67.44 a	0.63 d
6 dS. m^{-1} (S1)	67.76	47.21 c	1.75 c
12 dS. m^{-1} (S2)	42.71	47.21 c	4.24 b
18 dS. m^{-1} (S3)	71.61	56.52 b	8.95 a
A x S			
A1S0	57.16	77.71	0.39
A1S1	71.29	53.31	1.67
A1S2	43.03	51.38	2.72
A1S3	58.45	61.66	4.62
A2S0	73.86	57.16	0.87
A2S1	64.23	41.10	1.82
A2S2	42.39	43.03	5.76
A2S3	84.78	51.38	13.28

Numbers in the same column followed by the same letter are not significantly different in Duncan's Multiple Range Test at a significant level of 5%

Table 5. Air salinity effect on the yield of cabbage and cauliflower (t. ha^{-1})

Treatment	Air salinity (dS. m^{-1})				Average
Crops type	**0 (S0)**	**6 (S1)**	**12 (S2)**	**18 (S3)**	
Cabbage (A1)	14.97	13.90	14.58	15.42	14.72 a
Cauliflower (A2)	10.67	11.45	10.36	8.10	10.14 b
Average	12.82	12.67	12.47	11.76	(-)

Numbers in the same column followed by the same letter are not significantly different in Duncan's Multiple Range Test at a significant level of 5%

Table 6. Stress Tolerant Index (STI) of cabbage and cauliflower under the air salinity stress

No	Air salinity (dS. m^{-1})	STI	
		Cabbage (A1)	Cauliflower (A2)
1.	6 (S1)	1.3 (t)	0.7 (mt)
2.	12 (S2)	1.3 (t)	0.7 (mt)
3.	18 (S3)	1.4 (t)	0.5 (mt)

STI = Stress Tolerance Index; STI < 0.5 crops are sensitive (s); 0.5 ≤ STI ≤ 1.0 crops are medium tolerant (mt); STI > 1.0 crops are tolerant (t).

S3) crop could still give a crop yield of 12.43 t. ha^{-1} and had not experienced a significant decrease in yield.

Stress tolerance index (STI)

The results of quantifying the stress tolerance index (STI) between cabbage (A1) and cauliflower (A2) are shown in Table 6. The cabbagge (A1) exposed to air salinity at various concentrations showed that the STI quantification results were between 1.3 – 1.4, meaning that cabbage (A1) is classified as a crop species tolerant to air salinity at concentration 6 – 18 dS. m^{-1} (S1 – S3), while the results of quantification of STI on Cauliflower exposed to air salinity at various concentrations showed STI values between 0.5 – 0.7, meaning that cauliflower belonged to a moderate tolerance to air salinity at concentrations of 6 – 18 dS. m^{-1} (S1 – S3).

DISCUSSION

Growth inhibition due to air salinity depends on the length of the air salinity stress period received by crops in both the vegetative and generative stages. The response of crops to salinity stress appears to be osmotic stress in crops, which is the main factor in decreasing

the water supply of crop cells, so it has an impact on decreasing crop growth (Zaghdoud *et al.,* 2012). The salinity stress that can reduce crop growth is stress on soil salinity. Salinity stress in coastal land is affected by high salt concentrations in the soil due to salt accumulation (Mazhar, 2022). Salinization of the soil causes an increase in soil osmotic pressure and interferes with the absorption of water and nutrients in crops (Machado *et al.,* 2017). Salinity stress on the soil will reduce the ability of crops to obtain water and is called the osmotic impact of salinity. The osmotic effect on salinity will induce metabolic changes in crops, but this impact can affect crop growth depending on the exposure period to salinity stress (Patni *et al.,* 2020; Munss *et al*., 1995). Soil salinity causes a decrease in soil quality, thereby inhibiting root growth, decreasing nutrient uptake, and inhibiting enzymatic activity (Xian *et al.,* 2019).

The present study showed no decrease in plant height, leaf area, and cabbage and cauliflower dry weight due to the relatively short duration of exposure to air salinity (Table 2). In connection with the absence of an impact of air salinity on the growth of cabbage cauliflower, several factors influence this phenomenon, namely the period and object of exposure to air salinity stress. This phenomenon has a very different response when plants are exposed to salinity in the soil, where plant growth will decrease due to continuous exposure to soil salinity (Xian *et al*., 2019; Patni *et al*., 2020). Even though air salinity stress did not affect the growth of cabbage and cauliflower, morphologically, the cabbage and cauliflower showed differences in plant height and leaf area. However, the two crops did not make any difference in terms of dry weight. The shape and character of these crops influence the difference in leaf area between cabbage and cauliflower. Cabbage leaves generally tend to be short and wide, whereas cauliflowers are generally erect, longer, and narrower than cabbage leaves (Thapa *et al.,* 2019). Differences influence the diversity or differences in the appearance of crops in genetic makeup. Genetic diversity is a genetic strand expressed in a different stage or whole of growth, which is expressed in various crop traits that include crop forms and functions that produce crop growth diversity (Ginting *et al.,* 2013).

Regarding the physiological response, several studies have reported a decrease in leaf greenness and leaf chlorophyll levels when stressed by salinity (Sanoubar *et al.,* 2015; Jamil *et al.,* 2007; Taibi *et al.,* 2016; Shin *et al.,* 2020). The present study found that air salinity stress caused significant degradation of leaf greenness and chlorophyll content of cabbage and cauliflower (Table 3). Decreased chlorophyll content in crops subjected to salinity stress has been considered a hallmark of oxidative stress (Smirnof, 1996; Sharma *et al.,* 2021). It is associated with inhibiting chloro-synthesis and activating its degradation by chlorophyllase enzymes. The degradation of chlorophyll content due to slow synthesis or rapid breakdown of chlorophyll pigments indicates a photoprotection mechanism that reduces light absorption by reducing the chlorophyll content (Sanoubar *et al.,* 2015).

Degradation of chlorophyll content resulting in reduced light absorption impacts the photosynthetic performance of crops and stomatal conductance (Zörb *et al.,* 2018). The inhibition of photosynthesis caused by salinity stress is also affected by stomata's density and partial closure (Sahin *et al.,* 2018). In the present study, stomatal density decreased when the crop entered the generative stage (Table 4). The cause of stomatal density degradation and closure is osmotic stress caused by excessive salt accumulation and ion imbalance in leaves (Hannachi *et al.,* 2022). As a result of this osmotic stress, the plants respond to an increased accumulation of proline (Table 4). Increased salt concentration in the environment causes an increase in plant proline accumulation (Goharrizi *et al.,* 2020).

Proline accumulation for the plant will differ depending on its resistance to osmotic stress. The response of the cabbage plant to osmotic stress showed an accumulation of proline of 2.35 µmol g^{-1} FW. However, the accumulation of proline levels in the cabbage was much smaller than in cauliflower (Table 4). However, from all the physiological responses obtained due to air salinity stress, the production of cabbage and cauliflower did not significantly differ. Furthermore, based on the plant stress index, cabbage was tolerant to air salinity stress (1.3-1.4), and cauliflower was moderately tolerant to air salinity (0.5-0.7). Variations in the resistance of cabbage and cauliflower to water salinity were influenced by the plant's ability to produce proline during environmental stress. Cabbage is able to increase proline production higher than cauliflower. Proline is very beneficial in plants exposed to various stress conditions (Hayat *et al.,* 2012). In addition to acting as an excellent osmolyte, proline plays three major roles during stress by maintaining cell turgor or osmotic balance; stabilizing membranes, thereby preventing electrolyte leakage, and bringing concentrations of reactive oxygen species (ROS) within normal ranges, thus preventing oxidative burst in plants (Liang *et al*., 2013).

Conclusion

The research results showed that air salinity was not able to affect the growth and yield of cabbage (Grand 22) (A1) and cauliflower (Larisa F1) (A2). However, the physiological response showed that air salinity stress until 18 dS. m^{-1} (S3) could degrade leaf greenness in the vegetative phase (22.23%) and generative phase (18.37%), chlorophyll content in the vegetative phase (29.16%) and generative phase (37.88%), and stomata density (67.44%) and increase the accumulation of pro-

line content (1,320.63%). Then, tracing the stress tolerance index showed that cabbage (A1) was tolerant and cauliflower (A2) was moderately tolerant to air salinity. This present study showed that air salinity impacted physiological responses but has no impact on cabbage (A1) and cauliflower (A2) yields. Hopefully, this information will become a reference for cultivating cabbage and cauliflower on coastal land. However, additional studies are needed regarding the length of exposure to water salinity on cabbage and cauliflower yields.

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Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Alsuhendra (2004). Anti-Atherosclerotic Power of Zn-Chlorophyll Derivative from Cassava Leaves (*Manihot esculenta Crantz*) in Guinea Pigs. Disertasi. Sekolah Pascasarjana, Institut Pertanian Bogor, Bogor [Indonesian].
2. Anshori, M. F., Purwoko, B. S., Dewi, I. S., Ardie, S. W., Suwarno, W. B. & Safitri, H. (2018). Determination of selection criteria for screening of rice genotypes for salinity tolerance. *SABRAO J Breed Genet,* 50(3), 279-294.
3. Asian Development Bank. (2015). Summary of Indonesia's Agriculture, Natural Resources, and Environment Sector Assessment. Mandaluyong City, Philippines. https://www.adb.org/sites/default/files/publication/177036/ino-paper-08-2015.pdf.
4. Athulya, B. M., Priya, G., Rani, B., Aparna, B. & Nishan, M. A. (2023). Assessment of Soil Quality Index in the Southern Coastal Sandy Soils of Kerala, India. *Int. J. Environ. Clim. Change*, 13(8), 526-536. https://doi.org/10.9734/IJECC/2023/v13i81980.
5. Barus, W. A., Munar, A., Sofia, I. & Lubis, E. (2021). Contribution of Salicylic Acid to Salinity Stress Resistance in Plants. *Jurnal Penelitian Bidang Ilmu Pertanian*, 19(2), 9–19. [Indonesian].
6. Bates, L. S., Waldren, R. P. & Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. *Plant Soil,* 39, 205-207. https://doi.org/10.1007/BF00018060.
7. Central Statistical Agency (2021). Production of Vegetable Crops 2021 in Indonesia. https://www.bps.go.id/indicator/55/61/1/produksi-tanaman-sayuran.html.
8. Devi, N. D. & Arumugam, T. (2019). Salinity tolerance in vegetable crops: A review. *Journal of Pharmacognosy and Phytochemistry,* 8(3), 2717-2721.
9. Faozi, K., Yudono , P., Indradewa, D. , & Ma'as, A. (2021). The growth analysis of soybean cultivars on the application of banana pseudo-stem bokashi in Samas Coastal Land, Yogyakarta. *Ilmu Pertanian (Agricultural Science),* 6(1), 28-37. https://doi.org/10.22146/ipas.41531.
10. Ghosh, B., Mohamed, N. A. & Gantait, S. (2016). Response of rice under salinity stress: a review update. *Rice Res,* 4(2), 1-8. https://doi.org/10.4172/2375-4338.1000167.
11. Ginting, E. S. B., Bangun, M. K., & Putri, L. A. P. (2013). Growth Response and Production of Hybrid and Non-Hybrid Corn (*Zea mays L.*) Varieties to the Application of Pospat and Bokashi Fertilizers. *Jurnal Online Agroekoteknologi,* 1(2), 67–73. [Indonesian].
12. Giuffrida, F., Carla, C., Angelo, M., & Cherubino, L. (2016). Effects of salt stress imposed during two growth stages on cauliflower production and quality. *J. Sci. Food Agric.,* 97, 1552–1560. https://doi.org/10.1002/jsfa.7900.
13. Goharrizi, K. J., Baghizadeh, A., Afroushteh, M., Amirmahani, F. & Kermani, S. G. (2020). Effects of salinity stress on proline content and expression of Δ^1-pyrroline-5-carboxylate synthase and vacuolar-type H^+ subunit E genes in wheat. *Plant Genetic Resources: Characterization and Utilization,* 18(5), 334–342. https://doi.org/10.1017/s1479262120000350.
14. Hannachi, S., Steppe, K., Eloudi, M., Mechi, L., Bahrini, I. & Van Labeke, M. C. (2022). Salt Stress-Induced Changes in Photosynthesis and Metabolic Profiles of One Tolerant ('Bonica') and One Sensitive ('Black Beauty') Eggplant Cultivars (*Solanum melongena L.*). *Plants,* 11, 590. https://doi.org/10.3390/plants11050590.
15. Hayashi, K., Abdoulaye, T. & Wakatsuki, T. (2010). Evaluation of the utilization of heated sewage sludge for peri-urban horticulture production in the Sahel of West Africa. *Agricultural Systems,* 103, 36 – 44. https://doi.org/10.1016/j.agsy.2009.08.004.
16. Hayat, S., Hayat, Q., Alyemeni, M. N., Wani, A. S., Pichtel, J. & Ahmad, A. (2012). Role of proline under changing environments. *Plant Signaling & Behavior*, 7(11), 1456–1466. https://doi.org/10.4161/psb.21949.
17. Hnilickova, H., Kraus, K., Vachova, P. & Hnilicka, F. (2021). Salinity Stress Affects Photosynthesis, Malondialdehyde Formation, and Proline Content in *Portulaca oleracea L. Plants,* 10, 845. https://doi.org/10.3390/plants10050845.
18. Hooshmandi, B. (2019). Evaluation of tolerance to drought stress in wheat genotypes. *IDESIA (Chile),* 37 (2), 37-43.
19. Imahori, Y. (2014). Role of ascorbate peroxidase in post-harvest treatments of horticultural crops. Oxidative Damage to Plants: Antioxidant Networks and Signaling. Elsevier Inc., pp. 425–451. https://doi.org/10.1016/B978-0-12-799963-0.00014-9.
20. Jamil, M., Rehman, S., Lee, K. J., Kim, J. M., Kim, H. & Rha, E. S. (2007). Salinity Reduced Growth PS2 Photochemistry and Chlorophyll Content in Radish. *Sci. Agric. (Piracicaba, Braz.),* 64 (2), 111-118.
21. Liang, X., Zhang, L., Natarajan, S. K. & Becker, D. F. (2013). Proline Mechanisms of Stress Survival. *Antioxid. Redox Signal,* 19 (9), 998–1011. https://doi.org/10.1089/ars.2012.5074.
22. Machado, R. M. A. & Serralheiro, R. P. (2017). Soil Salinity: Effect on Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization. *Horticulturae,* 3(30). https://doi.org/10.3390/horticulturae3020030.
23. Mazhar, S., Pellegrini, E., Contin, M., Bravo, C. & De No-

bili, M. (2022). Impacts of salinization caused by sea level rise on the biological processes of coastal soils - A review. *Front. Environ. Sci*., 10, 909415. https://doi.org/10.3389/fenvs.2022.909415.
24. Munns, R., Schachtman, D. P. & Condon, A. G. (1995). The significance of a two-stage growth response to salinity in wheat and barley. *Funct. Plant Biol.,* 22, 561–569.
25. Nasrudin and Kurniasih, B. (2021). The agro-physiological characteristics of three rice varieties affected by water depth in the coastal agricultural land of Yogyakarta, Indonesia. *Biodiversitas,* 22(9), 3656-3662. https://doi.org/10.13057/biodiv/d220907.
26. Nugroho, A. D. (2021). Does Covid-19 have effects on the Indonesian horticultural subsector?. *Bulg. J. Agric. Sci.,* 27 (5), 865–874.
27. Patni, B., Bhattacharyya, M. & Singh, S. K. (2020). Biochemical Mechanisms to Defend Salinity Stress in Cabbage Family Members. *Adv Crop Sci Tech,* 8, 433.
28. Putra, F. P., Yudono, P. & Waluyo, S. (2017). Growth and Yield of Upland Rice Under Intercropping System with Soybean in Sandy Coastal Area. *Ilmu Pertanian (Agricultural Science)*, 2 (3), 130-136. https://doi.org/10.22146/ipas.25215.
29. Radanielson, A. M., Angeles, O., Li, T., Ismail, A. M., & Gaydon, D. S. (2017). Describing the physiological responses of different rice genotypes to salt stress using sigmoid and piecewise linear functions. *Field Crops Res,* 220, 46-56. https://doi.org/10.1016/j.fcr.2017.05.001.
30. Ruel, T., Quisumbinga, A. R. & Balagamwala, M. (2018). Nutrition-sensitive agriculture: What have we learned so far? *Global Food Security,* 17, 128–153. https://doi.org/10.1016/j.gfs.2018.01.002.
31. Sahin, U., Ekinci, M., Ors, S., Turan, M., Yildiz, S. & Yildirim, E. (2018). Effects of individual and combined effects of salinity and drought on physiological, nutritional and biochemical properties of cabbage (*Brassica oleracea* var. *capitata*). *Scientia Hort.,* 240, 196–204.
32. Sanoubar, R., Cellini, A., Veroni, A. M., Spinelli, F., Masia, A., Antisari, L. V., Orsini, F. & Gianquinto, G. (2015). Salinity thresholds and genotypic variability of cabbage (*Brassica oleracea* L.) grown under saline stress. *J Sci Food Agric,* 96, 319–330. http://dx.doi.org/10.1002/jsfa.7097.
33. Saparso, Subiyanti-Harsono & Tohari. (2003). Development of Cabbage on Coastal Sand Land: Plant Growth on Various Combinations of Mulch and Methods of Nitrogen Fertilization. *Agrin*., 7(2), 60-73 [Indonesian].
34. Servina, Y. (2019). Climate Change Impacts and Adaptation Strategies for Fruit and Vegetable Plants in the Tropics. *Jurnal Penelitian dan Pengembangan Pertanian*. 38 (2): 65–76 [Indonesian].
35. Saparso, Tohari, Shiddieq, D. & Setiadi B. (2009). Environmental determinants of cabbage production in coastal sandy soils. *J. Hort.,* 19, 301-312 [Indonesian].
36. Sharma, J. K., Sihmar, M., Santal, A. R. & Singh N. P., (2021). Physiological and biochemical responses of seedlings of six contrasting barley (*Hordeum vulgare L*.) cultivars grown under salt-stressed conditions. *Journal of Applied and Natural Science*, 13(3), 1020 -1031. https://doi.org/10.31018/jans.v13i3.2863.
37. Shin, Y. K. S., Bhandari, S. R., Jo, J. S., Song, J. W., Cho, M. C., Yang, E. Y., & Lee, J. G. (2020). Response to Salt Stress in Lettuce: Changes in Chlorophyll Fluorescence Parameters, Phytochemical Contents, and Antioxidant Activities. *Agronomy,* 10, 1627; http://dx.doi.org/10.3390/agronomy10111627.
38. Smirnoff, N. (1996). Botanical briefing: the function and metabolism of ascorbic acid in plants. *Annals of Botany,* 78, 661–669.
39. Taïbi, K., Taïbi, F., Abderrahim, L. A., Ennajah, A., Belkhodja, M. & Mulet, J. M. (2016). Effect of salt stress on growth, chlorophyll content, lipid peroxidation and antioxidant defence systems in *Stageolus vulgaris L*. *South African Journal of Botany,* 105, 306-312. http://dx.doi.org/10.1016/j.sajb.2016.03.011.
40. Thapa, B., Pandey, P., Paudel, S., Dahal, K. C., Khanal, A. & Shrestha, A. (2019). Effect of Seedling Density on Morphological Attributes of Cabbage, Cauliflower and Broccoli under Protected Condition. *Global Journal of Science Frontier Research: D Agriculture and Veterinary,* 19(3), 1-11.
41. Ukaegbu, E. P. & Nnawuihe, C. O. (2020). Assessing landuse effect on soil properties in the Coastal plains sand, Imo State, Nigeria. *Afr. J. Agric. Res.*, 16(6), 850-859. http://dx.doi.org/10.5897/AJAR2018.13809.
42. Xian, X., Pang, M., Zhang, J., Zhu, M., Kong, F., & Xi, M. (2019). Assessing the effect of potential water and salt intrusion on coastal wetland soil quality: simulation study. *J. Soils Sediments,* 19, 2251–2264. https://doi.org/10.1007/s11368-018-02225-y.
43. Zaghdoud, C., Alcaraz-López, C., Mota-Cadenas, C., Martínez-Ballesta, M. C., Moreno, D. A., Ferchichi, A. & Carvajal, M. (2012). Differential responses of two broccoli (*Brassica oleracea L.* var *italica*) cultivars to salinity and nutritional quality improvement. *S World J,* 291435.
44. Zörb, C., Geilfus, C. M., & Dietz, K. J. (2018). Salinity and crop yield. *Plant Biol.,* 21, 31–38.