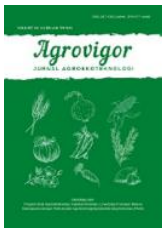
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Article

Effect of Compost Tea and Diluted Sea Water on Growth, Yield, and Chlorophyll Content of Pak Choi (*Brassica rapa* L.)

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ABSTRACT

A combination of Diluted Sea Water (DSW) and Aerated Compost Tea (ACT), as a nutrient source, may increase yield of Pak Choi (*Brassica rapa* L.). The study investigating the interaction effects of DSW and ACT on growth and yield of Pak Choi was conducted at the greenhouse of Trunodjoyo University Madura from December 2022 – January 2023. This factorial experiment was arranged on a completely randomized design with two factors. The DSW factor consisted of two levels: S0 (0%) and S1 (3,0%). The ACT factor contained three levels: P0 (0%), P1 (6,0%), and P2 (12,0%). The combination resulted in six treatments: S0P0 (Control), S0P1 (6% ACT), S0P2 (12% ACT), S1P0 (3% DSW), S1P1 (3% DSW + 6% ACT), and S1P2 (3% DSW + 12% ACT). Each treatment was replicated for four times, totaling 24 experimental units. Data were analyzed using ANOVA ($p < 0.05$) and mean differences were analyzed by DMRT ($p < 0.05$). Results showed that interaction of DSW and ACT significantly increased plant height, leaf number, leaf area, fresh and dry weight, and chlorophyll content with the S1P2 treatment yielding the best result. Plant yield and chlorophyll content under S1P2 was respectively 25% and 19% higher than the control. Effects of higher concentration of DSW and ACT on plant growth and yield as well as the changes of soil characteristics warrant for further study.

INTRODUCTION

Pak Choi (*Brassica rapa* L.) is a green leafy vegetable that has a high potential to prevent human health. The plant contains non-nutritive bioactive, such as anthocyanins, flavonoids, kaempferol, quercetin, and glucosinolates that performs antioxidant effect (Raiola et al., 2017). Many other nutritious compounds, including vitamins, minerals, and dietary fiber, that protect chronic diseases, such as inflammation, cancer, Alzheimer's, cardiovascular disease, and other diseases (Naseri, 2024). Therefore, the availability of this vegetable has to be prevented sustainably.

Such efforts have commonly been practiced by employing inorganic fertilizer as main nutrient sources for the plant, as the nutrients become available more quickly (Jayanti, 2020). However, the intensive use of this fertilizer could result in low quality of yield of vegetable having high nitrate content and low antioxidant compounds (Biondi et al., 2021; Chausali and Saxena, 2021; Nguyen et al., 2025) and could create environmental problems as well (Zhou et al., 2023). Additionally, if fertilizer prices increase, it will reduce profits. Moreover, to sustain high yield of the vegetable to meet the consumption need is facing climate change and scarcity of water resource. Therefore, alternative uses of nutrient sources which are available in nature locally, such as organic fertilizers and seawater are needed with sustainably system.

The use of organic fertilizers improves yield quality of vegetable. Organically grown food crops have higher quality, specifically in the content of bioactive compounds with antioxidant function (Biondi et al., 2021; Ramiya et al., 2021), such as vitamin C, and phenol (Ahmed et al., 2021; Muscolo et al., 2020; Li et al., 2017; Pereira, and de Angelis-Pereira, 2022; Nguyen et al., 2025) but significantly less nitrates (Karnpanit et al., 2018; Li et al., 2017; Petpiamsiri et al., 2018; Wang et al., 2022; Nguyen et al., 2025). Although nitrate has important role in human body to defence against gastroenteritis (Schlagenhauf, 2022), lower Nitrate content in vegetable make product save to be consumed as it may not cause thyroid problems, various kinds of human cancers, neural tube defects (during fetus development), and diabetes (Ahmed et al., 2017).

Moreover, organic fertilizers improve soil properties and increase available nutrients and organic matter in the soil (Liu et al., 2024). For example, the application of cow and chicken manure decreased bulk density and increased porosity, thereby increasing the percentage of maize plant roots at a depth of 0-15 cm, and ultimately increasing the root and stem biomass of maize plants, with chicken manure being more effective than cow manure (Amjad et al., 2016). Furthermore, organic management enhanced nitrogen mineralization with comparatively higher microbial biomass and enzymatic activities in soil (Chausali and Saxena, 2021). However, the nutrients from organic fertilizers are usually available slowly, so other technologies are needed to increase their availability rate. To increase the availability rate of nutrients, organic fertilizers can be applied in liquid form, such as compost tea.

Compost tea can provide nutrients for plant and perform as biocontrol agent to protect plant from disease infection (Garg and Rakshit, 2024). Compost tea had benefit effects on increasing crop growth, yield and final quality as well as soil characteristics, and suppressed plant diseases, where these effects were influenced by the process of compost production (Pilla et al., 2023; Yin, et al., 2025). Compared to non- aerated compost tea, aerated one besides provides nutrients for plant, it also had more capability to protect cultivated plant against plant's diseases (Pilla et al., 2023). Effect compost tea on growth and yield of tomato influenced by concentration, where 1 compost : 25 water increased significant growth and yield, with no significant different between foliar and soil application, but the soil application resulted higher N, P, K availability (Abubaker et al., 2024). As a soil amendment compost tea has a capacity to enhance available nutrients, maintain water holding capacity and soil organic matter, increase soil microbial diversity, and suppres plant diseases (Pilla et al.,2023). The capacity of plant-disease suppresivity may depend on the presence of particular microorganisms indigenous in compost tea and its relates to the time of brewing (Morales-Corts et al., 2018).

Seawater contains a variety of elements, from macro and micronutrients to rare earth elements, which have the potential to improve plant quality. Rare earth elements in low concentrations can increase the yield and quality of plant products (Adisa et al., 2018; Thomasi et al., 2021). However, seawater also contains various salts, including 55% Cl, 31% Na, 8% SO4-2, 4% Mg, 1% Ca, 1% K, and the remainder consisting of bicarbonate, bromide, boric acid, strontium, and fluoride (Helmi et al., 2020), which can cause salinity

effects if used directly on plants. Salinity to certain stage may improve yield quality of vegetable (Abdelkader et al. 2024; Ghoname et al. 2019; Meyer et al. 2021), but exesesive salinity could hinder growth and yield (Abdelkader et al. 2024; Ghoname et al. 2019). Therefore, to eliminate the salinity effect, seawater is diluted with freshwater, also known as Diluted Sea Water (DSW) (Hanh et al., 2021). DSW can act as a nutrient source for the production of various fruit and vegetable crops; when (Javeed et al., 2021). DSW combined with other inputs can stimulate the growth of beneficial microorganisms that can help suppress diseases (Wang et al., 2022).

This research investigates the effects of a combination of diluted seawater and compost tea on the growth and yield as well quality of pak choi vegetable. In this research, the local resources, diluted sea water and tea compost, as the source of nutrients, to replace inorganic fertilizers in cultivation of *Brassica rapa,* Previous research has mostly examined compost tea or diluted water separately, leaving a gap in understanding their combined effect to replace synthetically chemical fertilizer, particularly in the cultivation of popular vegetable, *Brassica rapa*. By testing specific concentration of diluted sea water combined with varying tea compost concentrations, this work provides new insights into optimizing growth and yield as well as yield quality of *Brassica rapa*. The findings contribute to sustainable vegetable management without synthetically chemical fertilizer and hence enhance practical recommendations for environmentally friendly *Brassica rapa* cultivation systems.

MATERIALS AND METHOD

This research was conducted at the greenhouse of the Faculty of Agriculture, Trunodjoyo Madura University from December 2022 to January 2023. The equipment used included tubs, an aerator, a digital scale, 25 cm diameter pots, pot trays, a ruler, treatment labels, and a spectrophotometer. The materials used were Nauli F1 Pak Choi seeds, Aseton PA, soil (air-dried, passed through a 2.0 mm sieve), AC condensation water, aerated compost tea (ACT) (made by dissolving compost (composed of rice husk biochar, chicken manure, and legume litter) with water at a ratio of 1:6; compost:water; v:v) that was aerated with an aquarium aerator, and seawater (taken from Kamal Beach, Madura, at a depth of 30 cm from the surface).

The experimental design used was a factorial Completely Randomized Design (CRD) with 2 factors: diluted seawater (DSW) and aerated compost tea (ACT). The DSW factor consisted of two levels: S0 (0% seawater) and S1 (3% seawater, equivalent to 6.0 mL). The second factor (ACT) consisted of three levels: P0 (0%), P1 (6%, equivalent to 12.0 mL), and P2 (12%, equivalent to 24.0 mL). The combination of these two factors resulted in 6 treatment combinations (Table 1), and each treatment was replicated 4 times, resulting in a total of 24 experimental units.

Table 1. Treatment combinations of diluted seawater (DSW) and aerated compost tea (ACT) application

Treatment Code	Description
S0P0	Control (without diluted seawater and compost tea application)
S0P1	0.0 mL seawater + 12.0 mL compost tea (0% seawater + 6% compost tea)
S0P2	0.0 mL seawater + 24.0 mL compost tea (0% seawater + 12% compost tea)
S1P0	6.0 mL seawater + 0 mL compost tea (3% seawater + 0% compost tea)
S1P1	6.0 mL seawater + 12.0 mL compost tea (3% seawater + 6% compost tea)
S1P2	6.0 mL seawater + 24.0 mL compost tea (3% seawater + 12% compost tea)

Two-week-old Pak Choi seedlings were planted in pots containing 2.0 kg of soil. The treatments of diluted seawater and compost tea with concentrations as listed in the table were applied four times: at 7, 14, 21, and 28 days after planting (DAP). Parameters investigated were plant height, number of leaves, and leaf area at 7, 14, 21, 28, and 35 DAP, as well as plant fresh and dry weight and leaf chlorophyll content (a, b, and total), investigated after harvest (35 DAP). Plant height was measured from the base of the stem (the surface of the growing medium) to the highest part of the plant using a ruler in centimeters (cm). The number of leaves was determined by counting the fully expanded, green leaves on each sample plant. Leaf area

was investigated by multiplying the length and width of the leaf and constant (0,6825). Fresh weight was determined by weighing the entire fresh plant (including roots and leaves, which had been washed and air-dried), using a digital scale and the results were expressed in grams (g). Dry weight of the plant measured by weighing the dried plant (divided into three parts—leaves, stems, and roots—and placed into perforated envelopes, and were then oven-dried for 48 hours at 70°C). Chlorophyll content was determined by measuring the absorbance of diluted plant extract with acetone using a spectrophotometer at the wavelengths of 645 (A645) and 663 nm (A663), and then calculated as follow: Chlorophyll a (mg/g) = [(12.7 x A663) – (2.69 x A645)] x 0.02; Chlorophyll b (mg/g) = [(22.9 x A645) – (4.68 x A663)] x 0.02; and Total Chlorophyll a (mg/g) = [(20.2 x A645) + (8.02 x A663)] x 0.02. The data were analyzed using ANOVA ($p < 0.05$) to determine effect of the treatments and the differences among means were determined by Duncan's Multiple Range Test (DMRT) ($p < 0.05$).

RESULTS AND DISCUSSION

Plant Height

Results of ANOVA ($p < 0.05$) and DMRT ($p < 0.05$) for plant height from 7 to 35 DAP due to the diluted seawater and compost tea treatments were presented in Table 2. Based on Table 2, there is an interaction effect between diluted seawater and compost tea on plant height at 28 and 35 DAP. At the end of the observation period (35 DAP), the S1P2 treatment had the highest average value, which was 20% higher than the plant height in the Control treatment (S0P0). It is also observed that the addition of diluted seawater consistently resulted in a higher average plant height compared to treatments without diluted seawater.

Table 2. The average height of Pak Choi plants (cm) due to seawater (DSW) and compost tea (ACT) treatments at 7, 14, 21, 28, and 35 DAP

Plant age (DAP)	Treatments				Average
	DSW	ACT			
		P0	P1	P2	
7	S0	3,43	3,73	3,42	3,53
	S1	3,81	3,90	3,56	3,76
	Average	3,62	3,82	3,49	
14	S0	4,55	5,43	5,17	5,05
	S1	4,87	4,63	4,58	4,69
	Average	4,17	5,03	4,87	
21	S0	5,62	6,02	5,81	5,82
	S1	5,65	6,40	5,88	5,98
	Average	5,63	6,21	5,84	
28	S0	6,45 a	6,87 b	6,89 b	6,74 a
	S1	6,62 b	7,25 c	7,45 c	7,11 b
	Average	6,53 a	7,06 b	7,17 b	
35	S0	7,11 a	7,92 b	7,73 b	7,59 a
	S1	7,84 b	8,22 c	8,56 d	8,21 b
	Average	7,47 a	8,07 b	8,15 b	

Note: Numbers followed by the same letter are not significantly different according to DMRT ($p < 0.05$).

Leaf Number

Results of ANOVA ($p < 0.05$) and DMRT ($p < 0.05$) on the number of leaves parameter at 7 - 35 DAP due to the effect of diluted seawater and compost tea treatments are presented in Table 3. Data on Table 3 show evident that the S1P2 treatment (3% seawater + 12% compost tea; v/v) at 35 DAP (Days After Planting) yielded the highest average number of leaves, which was 16.4% higher compared to the number of leaves in the S0P0 (Control).

Table 3. Average number of leaves of Pak Choi plants due to diluted seawater (DSW) and compost tea (ACT) treatments at 7, 14, 21, 28, and 35 DAP

Time Measurement (DAP)	Treatments				Average
	DSW	ACT			
		P0	P1	P2	
7	S0	3,92	3,92	4,00	3,94
	S1	4,00	3,75	3,83	3,86
	Average	3,96	3,83	3,92	
14	S0	6,25	6,33	6,25	6,28
	S1	6,42	6,67	5,92	6,33
	Average	6,33	6,50	6,08	
21	S0	8,75	9,08	9,25	9,03
	S1	9,08	8,92	9,17	9,06
	Average	8,92	9,00	9,21	
28	S0	10,42	10,50	10,67	10,53 a
	S1	10,92	10,75	11,42	11,03 b
	Average	10,67 a	10,62 a	11,04 b	
35	S0	12,67 a	13,17 ab	13,33 b	13,06 a
	S1	13,58 b	13,50 b	14,75 c	13,94 b
	Average	13,12 a	13,33 a	14,04 b	

Note: Numbers followed by the same letter are not significantly different according to DMRT ($p < 0.005$).

Leaf Area, Fresh and Dry Weight

Results of ANOVA ($p < 0.05$) and DMRT ($p < 0.05$) indicate that the combination treatment of seawater and compost tea, as well as the single treatments of each factor, had a significant effect on the average leaf area, fresh weight, and dry weight of Pak Choi plants. The average leaf area, fresh weight, and dry weight of Pak Choi plants resulting from the seawater and compost tea treatments are presented in Table 4.

Table 4. Average leaf area, fresh and dry weight of Pak Choi due to DSW and ACT

Parameters	Treatments				Average
	DSW	ACT			
		P0	P1	P2	
Leaf Area (cm^2)	S0	391,91 a	433,07 b	486,06 c	437,01 a
	S1	490,63 c	493,68 c	544,29 d	509,20 b
	Average	441,27 a	462,87 b	515,17 c	
Fresh Weight (g)	S0	43,95 a	45,92 a	49,65 bc	46,51 a
	S1	51,38 c	48,65 b	55,04 d	51,69 b
	Average	47,67 a	47,29 a	52,34 b	
Dry Weight (g)	S0	4,40 a	4,58 a	5,51 c	4,83 a
	S1	5,13 b	5,23 bc	5,64 c	5,53 b
	Average	4,76 a	4,90 a	5,57 b	

Note: Numbers followed by the same letter are not significantly different according to DMRT($p < 0.05$).

Based on Tables 4, it is evident that the S1P2 treatment (3% seawater + 12% compost tea; v/v) exhibited the highest average values for leaf area, fresh weight, and dry weight; the respective increases for each parameter were 39%, 25%, and 28% compared to the values of those parameters in the S0P0 (Control) treatment.

Chorophyl Content

Results of ANOVA ($p < 0.05$) and DMRT ($p < 0.05$) for chlorophyll parameters indicate that the

combination treatment of seawater and compost tea had a significant effect on the average levels of chlorophyll a, chlorophyll b, and total chlorophyll in Pak Choi plants. Single treatments of seawater and compost tea also significantly affected the average chlorophyll a, chlorophyll b, and total chlorophyll levels in Pak Choi plants at the end of the observation period. The average chlorophyll content of Pak Choi plant leaves resulting from the seawater and compost tea treatments is presented in Table 5.

Tabel 5. Average of chlorophyl (a,b, and total) content of Pak Choi due to application of DSW and ACT

Parameters	Treatments				Average
	DSW	ACT			
		P0	P1	P2	
Chlorophyll a (mg/g)	S0	0,32 a	0,33 b	0,34 bc	0,33 a
	S1	0,34 bc	0,33 b	0,36 c	0,34 b
	Average	0,33 a	0,33 a	0,35 b	
Chlorophyll b (mg/g)	S0	0,26 ab	0,30 b	0,28 ab	0,28
	S1	0,31 b	0,25 a	0,34 b	0,30
	Average	0,28 ab	0,27 a	0,31 b	
Total Chlorophyll (mg/g)	S0	0,58 a	0,63 b	0,63 b	0,62 a
	S1	0,64 c	0,60 b	0,69 c	0,64 b
	Average	0,61 a	0,62 a	0,66 b	

Note: Numbers followed by the same letter are not significantly different according to DMRT($p < 0.05$).

Based on Table 5, it appears that the treatment S1P2 (1.5 mL of seawater + 6 mL of compost tea dissolved to 50 mL) tends to have the highest average values for chlorophyll a, b, and total content. The sequential increases in chlorophyll a, b, and total content were 13%, 31%, and 19% compared to the chlorophyll levels in the S0P0 (control) treatment.

DISCUSSION

The mixture of the DSW and the ACT significantly increased plant growth, and at the end of the study (at harvest), the S1P2 treatment (3% seawater + 12% compost tea; v/v) yielded the highest plant height (20% higher than the average plant height in the control), the highest number of leaves (14.75 leaves) (16.4% higher than the average number of leaves in the control plants), and the highest leaf area (544.29 cm^2, 39% higher than the average leaf area of the control treatment). These results indicate a synergistic effect between diluted seawater and compost tea in influencing plant growth. It is suspected that the nutrients present in seawater and compost tea have a positive effect on plants, for example, in protein formation and plant photosynthesis (Novita et al., 2022). Furthermore, Abuk (2021) stated that the application of seawater could increase the height of mustard plants. The application of compost tea to Pak Choi plants improves the availability of nutrients, especially N (Berek, 2017), which is highly needed by Pak Choi in the vegetative phase (Fatin et al., 2022). With increased N absorption, the meristematic tissue will be more active in cell division, thus increasing plant height. Leaf formation in plants, which increases the number of leaves per plant, is influenced by the nutrients absorbed by the plant (Panataria et al., 2020). Sufficient N availability will cause the plant leaves to grow wider and expand the surface area available for photosynthesis (Rianti et al., 2019). Nitrogen plays a role in accelerating plant height growth, the number of branch tillers, and chlorophyll formation in leaves (Fauzi et al., 2022).

Furthermore, the research results show that the interaction between the DSW and the ACT significantly increased the yield of Pak Choi plants. The S1P2 treatment (3% seawater + 12% compost tea; v/v) produced the highest fresh and dry weight of plants, which were 55.04 g/plant (25% higher than the average fresh weight in the control) and 6.15 g/plant (28% higher than the average dry weight in the control), respectively. Large plant growth will produce high biomass, and conversely, when plant growth is small, the resulting plant biomass will be low (Joko et al., 2024). The increase in plant dry weight is related to plant metabolism or the presence of better plant growth conditions for more efficient photosynthesis (Wu

et al., 2025). The main components of plant dry matter are the constituents of biomass, consisting of polysaccharides and lignin in the cell walls, plus cytoplasmic components such as proteins, lipids, amino acids, and organic acids. Dry weight is an indication of successful plant growth, because dry weight shows the net results of plant metabolism such as photosynthesis (Manurung et al., 2020).

The application of the DSW and the ACT also significantly increased the total chlorophyll concentration. The highest average value was found in the S1P2 treatment. The total chlorophyll in this treatment was 19% higher than the total chlorophyll in the S0P0 treatment (control). However, the total chlorophyll concentration in this study was low compared to the results of Fatin et al., (2022) in Pak Choi plants, which could reach 1.80 mg/g. According to Veazie et al., (2020), as the total chlorophyll content of Pak Choi is <1.00 mg/g, it is caused by a lack of N. Nitrogen is a basic element in several compounds, including amino acids, proteins, and nucleic acids that make up the entire protoplasm and chlorophyll formation (Novriani et al., 2022). Given the importance of N, for further research, the availability of this element needs to be increased. If inorganic sources such as Urea are avoided, then increasing the concentration of compost tea and seawater becomes an option. Besides N, elements that play a role in chlorophyll formation in Pak Choi include Fe, B, and Mg (Veazie et al., 2020). The micro-nutrient Mn can also support the absorption of N nutrients in plants, and the element Mo plays a role in binding N (Yama and Kartiko, 2020). Based on the research by Veazie et al., (2020), Pak Choi plants produce lower chlorophyll a and b compared to the control when there is a deficiency of Fe nutrients. Micro-nutrients found in seawater play a role in increasing the chlorophyll content of Pak Choi plants, including magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), boron (B), and molybdenum (Mo) (Javeed et al., 2021). Chlorophyll b in plants functions as a light harvester that is transferred to the reaction center. The reaction center is composed of chlorophyll a, where light energy will be converted into chemical energy and used for the reduction process in photosynthesis (Dharmadewi, 2022).

The application of compost tea may be able to maintain soil organic matter (Manggas et al., 2021). The optimization of soil organic matter availability and the normalization of soil salinity may be due to the microorganisms present in compost tea (Abuk, 2021). Soil salinity decreases due to the addition of organic fertilizers that can improve the physical properties of the soil and reduce the salt concentration in the root area (Ghazi, 2018). However, this study did not examine changes in soil characteristics, so further research is needed to comprehensively explain the causes of increased growth and yield. The results of this study indicate that diluted seawater (DSW) synergistically has a significant effect on the growth, yield, and quality of Pak Choi plants, which is thought to be due to the effect of the presence of rare earth elements (Adisa et al., 2018; Thomasi et al., 2021). Application of ACT alone in average increased the yield and chlorophyll content respectively up to 5,8% and 6,9% compared to that of Control, indicating DSW had highly significant effect on increasing growth and yield of Pak Choi plant. Application of increased concentration of DSW warrants for further study.

CONCLUSION

Interaction of compost tea (ACT) and diluted seawater (DSW) effectively increases the growth (plant height, number of leaves, leaf area), yield (fresh and dry weight of plants), and yield quality of Pak Choi (chlorophyll a, chlorophyll b, and total chlorophyll content), with the best treatment being S1P2 (3% DSW; 12% ACT:v/v). Compared to the control treatment, the increase in plant height, number of leaves, and leaf area in the S1P2 treatment were 20%, 16.4%, and 39%, respectively. The increases in fresh weight, dry weight, and total chlorophyll in the S1P2 treatment compared to the control treatment were 25%, 28%, and 19% respectively. Diluted seawater (DSW) (3%) and aerated compost tea (ACT) (12%) can be an alternative source of nutrients for Pak Choi plants. Further research is needed with higher concentrations of seawater and compost tea and their effects on plant growth and yield, as well as their effects on improving soil properties.

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AUTHORS CONTRIBUTIONS (Times New Roman 10)
SS was responsible for drafting and writing the original manuscript. ADM conducted the experimental work and was responsible for data collection, performed data analysis and statistical processing. CW interpreted the

research results and contributed to the discussion and conclusion of the study. All authors reviewed and approved the final manuscript.

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