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Efficacy of liquid seaweed extract as biostimulant on the performance of chinese kale *(Brassica oleracea* var. *alboglabra*)

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Abstract Result revealed that highly significant effect of seaweed extract application was observed in terms of plant weight at 30, 45 and 60 days after transplanting, plant height and length of root growth at 45 and 60 DAT. Width of the leaves were significantly differed at 30 and 45 days after transplanting. For nutrient uptake, T_2 (10 ml liter LSE: 1 liter of water) had the highest N, P, and K content compared to other treatments based on plant tissue analysis. However, different concentrations of liquid seaweed extract were significantly affected the length and number of leaves at 30, 45 and 60 days after transplanting.

Keywords: Biostimulant, Chinese kale, Liquid seaweed extract, Nutrient uptake, Organic fertilizer

Introduction

The insurmountable rising of cost of inorganic agricultural inputs is becoming a major concern for crop producers and is expected to remain difficult to control in future production seasons. Because of this situation, farmers are encouraged to explore alternative strategies that can sustain farm productivity while minimizing production expenses (DA-ATI, 2006). Recent data from the Philippine Statistics Authority revealed that inorganic fertilizer prices increased by 6.05% in 2023 compared with the previous year, mainly due to rising fuel costs and increasing market demand. Too much utilization of inorganic inputs may pose harmful impacts on both human and environment (USDA, 2009). It is therefore wise to evaluate alternatives that are environmentally safe, locally available and seemingly simple and easy to follow technology. This could be the use of liquid seaweed extract as biostimulant and biofertilizer in vegetable production primarily on Chinese kale production

Seaweed extracts are used as nutrient supplements, biostimulants, or biofertilizers in agriculture and horticulture to increase plant growth and yield

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(Hernandez, 2013). Seaweed and seaweed products have been used worldwide to increase plant growth and yield. In recent years, the use of natural seaweed as fertilizer has allowed for partial substitution of conventional synthetic fertilizer (Dhargalkar and Pereira 2005; Hong *et al*. 2007; Khan *et al*. 2009 and Zodape *et al*. 2010).

"Guso" or "tambalang" scientifically known as *Kappaphycus alvarezii,* is a seaweed that is locally known to contain good amount of nitrogen, phosphorous, potassium, minerals, trace elements. In addition, the carbohydrates and other organic matters present in this seaweed helps in altering the nature of the soil and in improving its moisture retaining capacity (Simpson and Hays, 2008). Brooth (2009) observed that the value of seaweed as fertilizer was not only due to nitrogen, phosphorous and potash content but, also the presence of trace elements and metabolites.

Chinese Kale *(Brassica oleracea var. alboglabra)* or leaf cabbage belongs to Brassicaceae family. It is a cool-weather crop that can tolerate temperatures as low as 20° F and prefers rich, well-drained soil with a soil pH between 5.5 and 6.8. Hence, it is best grown in full to partially shaded areas. It is considered as "Queen of the Greens" because of its nutrient-richness making it one of the most nutrient dense foods on the planet. Many powerful antioxidants are found in Chinese kale, including quercetin and kaempferol, which have numerous beneficial effects on health. It also contains high amount of Vitamin A, E, C, B6, and minerals such as Manganese, Copper, Calcium, Magnesium, Potassium. Moreover as one of the world's best sources of vitamin K, it is an important nutrient that is involved in blood clotting. A single cup of Chinese kale contains seven (7) times the RDA (*Recommended Dietary Allowances)* for vitamin K (Patterson, 2013).

Growing Chinese kale is so easy that even the most inexperienced gardener can grow it successfully. It is considered a high value crop that can be grown throughout the year and does not require so much space for them to grow and it suffers less from pests than most brassicas (Hull, 2016).

This study aimed to contribute in minimizing the impact of farm chemical inputs in the environment and to lessen the environmental threats by converting underutilized bio resource such as seaweeds into its useful form as organic fertilizer and biostimulant, and assessed the efficacy of liquid seaweed extract at different concentrations on the growth and yield and nutrient uptake of Chinese kale.

Materials and methods

Experimental site

The experiment was conducted at Cavite State University (CvSU) – Main Campus, Indang, Cavite, specifically at the Central Experiment Station (CES) greenhouse with clear plastic roof for better light interception, maintenance of th treatments and protection against torrential rains during the growing period from June to November 2018.

Crop establishment

T-Model variety of Chinese kale was used as subject crop. The growing medium composed an equal amounts of oridary garden soil, river sand and carbonized rice hull and was sent to laboratory for macronutrient and pH analysis prior to planting. Hot water treatment was performed to the media to lessen soil-borne pathogens and left undisturbed for two hours to allow cooling prior to seed sowing.

Suitable conditions was provided such optimum light, water and growth medium to support germination and early seedling establishment. Seeds were directly sown in seed boxes prior to pricking in the seedlimg trays for further growth. Hardening was done bby gradual exposure to outside light and reducing watering a week before transplanting to acclimatize to field settings.

After acclimatization, the seedlings were transplanted into individual polyethylene bags with dimension of 11 x11 x 17 inches. Each pot composed of approximately 3.5 kg of growing media of equal parts of ordinary garden soil and river sand. Watering was done twice daily to maintain soil moisture ensuring normal growth and development.

Treatment application and experimental design

The extract from fermented seaweed *Kappaphycus alvarezii* and molasses for a month was carried out in a laboratory for analysis of nutrient contents. Application was done as soil drench and foliar spray. The concentrations varied by treatment, and the seaweed extract was applied every seven days, beginning two weeks after transplanting. The pot experiment was laid out Completely Randomized Design (CRD) with five treatments, replicated three times, with 10 pots per replication. The treatments were applied as follows: T0: Control (water only), T1: 5 ml liquid seaweed extract per 1 liter of water (v/v), T2: 10 ml^{-L}, T3: 15 ml^{-L} and T4: 20 ml^{-L}.

Data gathering and sampling

Number of leaves per plant: Leaves were manually counted for each plant to evaluate the vegetative growth response to the treatments.

Plant height: The height of each plant was measured from the base to the tip using a ruler to assess the overall growth and development of the plant.

Weight of harvest: The weight of the whole plant, from root to tip, was measured using a digital weighing scale to assess the productivity of each treatment.

Root length: The longest root of each plant was measured from the base of the plant to the tip using a ruler.

Length and width of leaves: The longest leaf was measured for length and width using a ruler to assess leaf development and size.

Nutrient uptake: Tissue samples were collected after 60 days from 3 plants per treatment. These samples were analyzed at DA-STIARC Lipa City, Batangas, for nutrient content (N, P, K). To calculate nutrient uptake, plant tissue samples were collected and analyzed for nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) concentrations. The dry weight of each sample was determined by drying the tissue at 60–70°C until constant weight. Nutrient uptake was calculated using the formula:

$$\text{Nutrient uptake (g)} = \frac{Nutrient\ concentration\ (\%)}{100} \text{ x Dry weight (g)}$$

Statistical analysis

All quantitative data were tabulated, analyzed and summarized with the use of analysis of variance (ANOVA) in Completely Randomized Design (CRD). Comparison of treatment means was done using Duncan's multiple range test (DMRT) for significant or highly significant results.

Results

Soil media analysis

The analysis of soil media revealed that the ordinary garden soil contained 1.8 parts per million (ppm) of total available nitrogen, followed by the combination of both media with 0.6 ppm, while river sand had the least amount at 0.5 ppm (Table 1). For phosphorus, ordinary garden soil exhibited the highest level at 88 ppm, followed by the combination with 78 ppm, and river sand had

the least with 26 ppm. Regarding potassium, river sand contained the highest level at 250 ppm, followed by ordinary garden soil with 193 ppm, and the combination had the lowest at 159 ppm. In terms of pH, both river sand and the combination exhibited neutral pH values of 7.00 and 6.35, respectively, while ordinary garden soil had a slightly acidic pH of 6.13. Organic matter content of ordinary garden soil was highest at 1.8%, followed by the combination containing 1.2% and washed river sand had lowest OM of 0.5% only.

Table 1. Soil media analysis

SOIL MEDIA	TEXTURE	pH	ORGANIC MATTER (%)	N	P	K
				mg/kg or ppm		
Garden soil	Sandy clay loam	6.13	1.8	1.1	88	193
Riversand	Sand	7.00	0.5	0.4	26	250
Combination	Sandy loam	6.35	1.2	0.6	78	159
Remarks	**Ideal**	**Ideal**	**Low**	**Low**	**High**	**High**

Liquid seaweed extract analysis

Seaweed extract analysis showed that it contained 0.349% of total available nitrogen (N), 0.097% total available phosphorus (P_2O_5), and 1.658% total available potassium (K_2O) as shown in Table 2. The potassium content was within the ideal range (1.5–4.0%) for crucifers. Additionally, the pH of the concoction was measured at 4.19, indicating a strongly acidic characteristic.

Table 2. Laboratory analysis of liquid seaweed extract

NUTRIENT	VALUE
Total Nitrogen (N)	0.349%
Total Phosphorus (P_2O_5)	0.097%
Total Pottasium (K_2O)	1.658%
pH	4.19

Number of leaves

The number of leaves was manually counted at 30, 45, and 60 days after transplanting (DAT), starting from the matured leaves to the younger leaves. At 30 DAT, the lowest number of leaves per plant was observed in T0 (control) with 4.00, followed by T4 and T1, both with 4.33 leaves. The highest average number of leaves was recorded in T2, with 5.00 leaves (Table 3). Analysis of variance indicated that the different concentrations of liquid seaweed extract did not

significantly affect the number of leaves. This trend was consistent at 45 and 60 DAT as well.

Table 3. Leaf production across time as affected by LSE treatments

TREATMENT[1]	NUMBER OF LEAVES PER PLANT[2]		
	30 DAT[3]	45 DAT[3]	60 DAT[3]
T0-Control (water only)	4.00	5.67	7.33
T1- 5 ml^{-L}	4.33	6.00	7.33
T2- 10 ml^{-L}	5.00	6.67	8.00
T3- 15 ml^{-L}	4.67	6.63	7.67
T4- 20 ml^{-L}	4.33	6.00	7.33
CV (%)[4]	14.16	10.31	6.85

1T0-control (water only, T1- 5mL/L, T2- 10mL/L, T3- 15mL/L and T4-20 mL/L (LSE:Water) (v/v)
2For each growing period, values with similar between columns are not significantly different using DMRT at α=5%
3Growing periods (DAT-Days after transplanting): 30 DAT-early vegetative stage, 45 DAT- vegetative stage, and 60 DAT-maturity
4Coefficient of Variance

Plant height

Plant height increments (cm) were monitored starting at 30 days after transplanting (DAT) and subsequently at 15-day intervals and results are shown in Table 4. At 30 DAT, the highest average height was recorded in T2 with 34.133 cm, followed by T3 (29.367 cm), T1 (28.867 cm), and T4 (27.233 cm). The control (T0) had the lowest height at 24.933 cm.

Table 4. Plant height across time as affected by LSE treatments

TREATMENT[1]	PLANT HEIGHT[2] (cm)		
	30 DAT[3]	45 DAT[3]	60 DAT[3]
T0-Control (water only)	24.93	35.17^{c}	47.90^{c}
T1- 5 ml^{-L}	28.27	38.93^{bc}	50.63^{b}
T2- 10 ml^{-L}	34.13	45.73^{a}	54.67^{a}
T3- 15 ml^{-L}	29.37	43.17^{ab}	51.40^{b}
T4- 20 ml^{-L}	27.23	37.27^{c}	50.07^{b}
CV (%)[4]	6.27	6.65	2.24

1T0-control (water only, T1- 5mL/L, T2- 10mL/L, T3- 15mL/L and T4-20 mL/L (LSE:Water) (v/v)
2For each growing period, values with similar between columns are not significantly different using DMRT at α=5%
3Growing periods (DAT-Days after transplanting): 30 DAT-early vegetative stage, 45 DAT- vegetative stage, and 60 DAT-maturity

At 45 DAT, the application of different concentrations of liquid seaweed extracts significantly ($P<0.01$) affected plant height. Among the treatments, T2 exhibited the greatest height with a mean of 45.733 cm, followed by T3 (43.167

cm), T1 (38.933 cm), and T4 (37.267 cm). T0 (control) had the shortest plant height at 35.167 cm.

Furthermore, at 60 DAT, statistical analysis showed highly significant differences (*P<0.01*) in plant height across the varying concentrations of liquid seaweed extract. The plants treated with 10 ml of liquid seaweed extract in 1 liter of water (T2) exhibited the highest mean height of 54.667 cm, followed by T3 (51.400 cm), T1 (50.633 cm), and T4 (50.067 cm). T0 (control) had the lowest mean height at 47.900 cm.

Plant weight

The average weight of the plants was measured using a digital weighing scale at 30, 45, and 60 days after transplanting (DAT) and results are shown in Table 5. At 30 DAT, T2 recorded the highest weight at 37.67 grams, followed by T3 (37.67 grams), T1 (36.00 grams), and T4 (26.00 grams). The control (T0) had the lowest mean weight at 19.67 grams (Table 6). Statistical analysis revealed highly significant differences (*P<0.01*) in plant weight due to the varying concentrations of liquid seaweed extract. This trend was consistent at both 45 and 60 DAT.

Table 5. Plant weight across time as affected by LSE treatments

TREATMENT[1]	PLANT WEIGHT[2] (g)		
	30 DAT[3]	45 DAT[3]	60 DAT[3]
T0-Control (water only)	19.67^{c}	35.33^{e}	88.67^{b}
T1- 5 ml^{-L}	26.00^{b}	46.00^{c}	86.33^{b}
T2- 10 ml^{-L}	37.67^{a}	66.67^{a}	109.33^{a}
T3- 15 ml^{-L}	36.00^{a}	59.00^{b}	90.33^{b}
T4- 20 ml^{-L}	22.67^{bc}	41.00^{d}	85.67^{b}
CV (%)[4]	6.73	4.20	7.33

1T0-control (water only, T1- 5mL/L, T2- 10mL/L, T3- 15mL/L and T4-20 mL/L (LSE:Water) (v/v)
2For each growing period, values with similar between columns are not significantly different using DMRT at α=5%
3Growing periods (DAT-Days after transplanting): 30 DAT-early vegetative stage, 45 DAT- vegetative stage, and 60 DAT-maturity

Length of root growth

Root length was measured using a ruler from the base of the plant to the tip of the longest root at 30, 45, and 60 days after transplanting (DAT) and results are shown in Table 6. At 30 DAT, T2 exhibited the longest root with a mean length of 16.400 cm, followed by T3 (15.667 cm), T1 (15.300 cm), and T4 (14.067 cm). The control (T0) had the shortest root with a mean length of 13.233 cm. At 45 DAT, T2 again had the longest root with a mean length of 26.133 cm,

followed by T3 (24.767 cm), T1 (23.400 cm), and T4 (19.733 cm). The control (T0) showed the shortest root at 19.567 cm. This trend continued at 60 DAT, with T2 having the longest root and T0 (control) showing the shortest. Statistical analysis revealed highly significant differences (*P<0.01*) among the varying concentrations of liquid seaweed extracts evaluated for this parameter at 45 and 60 DAT.

Table 6. Length of root growth across time as affected by LSE treatments

TREATMENT[1]	LENGTH OF ROOT GROWTH [2] (cm)		
	30 DAT[3]	45 DAT[3]	60 DAT[3]
T0-Control (water only)	13.23	19.57[b]	20.17[c]
T1- 5 ml^{-L}	15.30	23.40[a]	24.40[b]
T2- 10 ml^{-L}	16.40	26.13[a]	29.53[a]
T3- 15 ml^{-L}	15.67	24.77[a]	25.57[b]
T4- 20 ml^{-L}	14.07	19.73[b]	20.17[c]
CV (%)[4]	4.65	4.65	5.39

1T0-control (water only, T1- 5mL/L, T2- 10mL/L, T3- 15mL/L and T4-20 mL/L (LSE:Water) (v/v)
2For each growing period, values with similar between columns are not significantly different using DMRT at α=5%
3Growing periods (DAT-Days after transplanting): 30 DAT-early vegetative stage, 45 DAT- vegetative stage, and 60 DAT-maturity

Length of the leaves

Leaf length was measured using a ruler at 30, 45, and 60 days after transplanting (DAT), from the base to the apex of the leaf and results are shown in Table 7. At 30 DAT, T2 produced the longest leaf with a mean length of 12.633 cm, followed by T3 (12.300 cm), T4 (10.933 cm), and T1 (9.433 cm). The control (T0) had the shortest leaf length at 9.067 cm.

Table 7. Leaf length across time as affected by LSE treatments

TREATMENT[1]	LEAF LENGTH [2] (cm)		
	30 DAT[3]	45 DAT[3]	60 DAT[3]
T0-Control (water only)	9.07	12.90	14.27
T1- 5 ml^{-L}	9.43	13.77	15.57
T2- 10 ml^{-L}	12.63	15.70	17.10
T3- 15 ml^{-L}	12.30	13.93	16.07
T4- 20 ml^{-L}	10.93	13.30	15.00
CV (%)[4]	14.11	9.35	7.00

1T0-control (water only, T1- 5mL/L, T2- 10mL/L, T3- 15mL/L and T4-20 mL/L (LSE:Water) (v/v)
2For each growing period, values with similar between columns are not significantly different using DMRT at α=5%
3Growing periods (DAT-Days after transplanting): 30 DAT-early vegetative stage, 45 DAT- vegetative stage, and 60 DAT-maturity

At 45 DAT, T2 again had the longest leaf with a mean length of 15.700 cm, followed by T3 (13.933 cm), T1 (13.767 cm), and T4 (13.300 cm). The control (T0) had the shortest leaf length at 12.900 cm. The same trend was observed at 60 DAT, with T2 having the longest leaf, followed by T3, T1, and T4. T0 (control) exhibited the shortest mean leaf length. Analysis of variance at 30, 45, and 60 DAT showed no significant effect of the treatments on leaf length.

Width of the leaves

Leaf width was measured using a ruler at 30, 45, and 60 days after transplanting (DAT), from the left to the right end of the leaf blade and results are shown in Table 8. At 30 DAT, T2 recorded the highest mean leaf width at 10.567 cm, followed by T3 (8.867 cm), T1 (8.767 cm), and T4 (7.833 cm). The control (T0) had the lowest mean width at 7.500 cm. Additionally, the width of the leaves was significantly ($P< 0.05$) influenced by the different concentrations of liquid seaweed extract at 30 DAT.

A similar trend was observed at 45 and 60 DAT, where T2 had the highest mean leaf width, followed by T3, T1, and T4. T0 exhibited the lowest mean width. These results suggest that T2 is the optimal concentration for significant increases in leaf width. Statistical analysis revealed significant ($P<0.05$) differences in leaf width at 45 DAT, but no significant differences were found at 60 DAT.

Table 8. Leaf width across time as affected by LSE treatments

TREATMENT[1]	**LEAF WIDTH [2] (cm)**		
	30 DAT[3]	**45 DAT[3]**	**60 DAT[3]**
T0-Control (water only)	7.50[b]	11.57[b]	14.28
T1- 5 ml^{-L}	8.77[ab]	12.33[b]	15.57
T2- 10 ml^{-L}	10.57[a]	14.97[a]	17.10
T3- 15 ml^{-L}	8.87[ab]	13.07[b]	16.07
T4- 20 ml^{-L}	7.83[b]	12.07[b]	15.00
CV (%)[4]	11.30	7.45	11.30

1T0-control (water only, T1- 5mL/L, T2- 10mL/L, T3- 15mL/L and T4-20 mL/L (LSE:Water) (v/v)
2For each growing period, values with similar between columns are not significantly different using DMRT at α=5%
3Growing periods (DAT-Days after transplanting): 30 DAT-early vegetative stage, 45 DAT- vegetative stage, and 60 DAT-maturity

Nutrient uptake

Nitrogen uptake (g): T2 showed the highest nitrogen uptake, with 0.447 grams, followed by T3 (0.357 grams), T1 (0.283 grams), and T4 (0.269 grams). The control (T0) had the lowest nitrogen uptake at 0.257 grams. This indicates that the application of liquid seaweed extract (especially at T2) significantly improved the nitrogen uptake by the plants compared to the control.

Phosphorus uptake (g): The highest phosphorus uptake was recorded in T2, with 0.079 grams, which was similar to T3 (0.079 grams). These values were higher than those observed in T1 (0.075 grams) and T4 (0.068 grams). The control treatment on the other hand obtained the lowest phosphorus uptake at 0.080 grams. This implies that seaweed extract at T2 improved the P uptake in crops, however there were little variations between treatments.

Potassium uptake (g): The T2 got the highest P uptake of 0.467 grams, followed by T3 with 0.463 grams, T1 (0.305 grams), and T4 (0.418 grams). Meanwhile, the control (T0) obtained the lowest P-uptake at 0.327 grams. The results show that application of the extract from fermented seaweed significantly enhanced P-uptake, with T2 garnering the highest value for this parameter.

Table 9. Nutrient uptake of chinese kale at maturity stage (60 DAT)

TREATMENT	NITROGEN UPTAKE (g)	PHOSPHORUS UPTAKE (g)	POTASSIUM UPTAKE (g)
T0-Control (water only)	0.257	0.080	0.327
T1- 5 ml^{-L}	0.283	0.075	0.305
T2- 10 ml^{-L}	0.447	0.079	0.467
T3- 15 ml^{-L}	0.357	0.079	0.463
T4- 20 ml^{-L}	0.269	0.068	0.418

Discussion

Based on the result of soil media analysis, it contained sufficient levels of phosphorus and potassium required for normal growth and development of Chinese kale, however the nitrogen content and organic matter were below the required amounts. Nitrogen is impotant in plant metabolism specifically in protein synthesis and vegetative development. Hence, lacking this may reduce vigor and overall plant performance (Hochmuth, 2016).

As opposed, phosphorus and potassium levels were within the acceptable amount which is vital for energy transfer, root performance and other

physiological functions in plants (Crop Nutrition, 2016). The levels of pH of the growing medium were characterized from neutral to slightly acidic, which is favorable for nutrient uptake and availability. Meanwhile, the low amount of organic matter may pose negative impact in soil structure, nutrient retention and water holding capacity (Brady, 2009). Increasing the availability of both nitrogen and organic matter could therefore contribute to enhanced plant performance (Ryczkowski, 2015).

After a month of fermentation of liquid seaweed extract, laboratory analysis revealed that it contained suitable for crop production. Laboratory analysis showed that the extract contained 0.349% total nitrogen (N), 0.097% phosphorus (P_2O_5), and 1.658% potassium (K_2O) that fall within the recommended range for crucifers (Kaiser, 2015). The extract is also acidic with a pH of 4.19 (Brady, 2009).

Unlike with other known utilized organic fertilizer, the liquid seaweed extract had relatively higher nitrogen and potassium concentrations than fish amino acid (FAA), fermented plant juice (FPJ) and other organic nutrient sources (Barcelon, 2004). These results signify that seaweed extract has potential as a biostimulant for crop production.

The number of leaves produced was not significantly affected by the extract application. Although numerical variations were observed among treatments, T2 got the highest mean number of leaves and the control, unsprayed had the lowest, however not statistically significant. This may be attributed with moisture availability in the soil media. The sandy characteristics of potting media resulted to the rapid water drainage and reduced water holding capacity, thereby affecting availability of nutrients imperative for ideal leaf production (Brady, 2009).

Height of plants was significantly affected by treatment applications at 45 and 60 days after transplanting (DAT). Among the concentrations, T2 consistently produced the tallest plants, highlighting the this effectively stimulated growth stages. The enhanced response may be associated with the presence of macro and microelements as well as the growth promoting substances generally present in seaweed extract, which have previously been shown to improve plant growth (Aldworth and Van Staden, 1987; Russo et al., 1994; Mohan *et al*., 1994).

The slower growth observed during the early vegetative phase at 30 DAT may be attributed to the initial lag phase of growth, during which smaller leaf surface area has lower photosynthetic efficiency (Kengsington, 2009). As plant

development progressed, the synergistic effects of seaweed extract became more pronounced.

Application of seaweed extract also enhanced plant weight. The highest biomass accumulation was consistently observed in T2, suggesting that application of 10 mLs seaweed extract was the most effective concentration for growth promotion.

Further, results suggest that concentration below or above the optimum level may lead to poor plant performance, possibly due to inadequate nutrients or excessive acidity that may inhibit growth (Mojica, 2010; Bautista and Venkatesalu, 2016). Similar effects of seaweed-based fertilizers on plant yield and biomass accumulation have been observed in some plant's species including *Zizyphus mauritiana* and other crops (Huyser, 1995; Mohan *et al*., 1994; Rajkumar and Subramanian, 1999).

Root development was similarly enhanced by treatment applications. The T2 consistently produced longest roots in all observation period, suggesting that the extract effectively stimulated root growth. Vigorous roots are vital during vegetative phase as it directly affects water and nutrient uptake. Previous studies have been reported improved root growth after application of seaweed extract derived from *Ecklonia maxima* due to naturally occurring cytokinins and other growth regulators (Featonby-Smith and Van Staden, 1983; Nelson and Van Staden, 1984). These results highlight the importance of promoting healthy root systems to support overall plant performance.

Leaf area including length and width was both enhanced by application of seaweed extract. Crop treated with T2 had the highest measurement across all observation periods, where the control treatment got the smallest leaves. Previous studies have likewise showed that seaweed extracr can stimulate vegetative growth and enhance leaf development. (Featonby-Smith and Van Staden, 1983a, b; Nelson and Van Staden, 1984). The improved leaf parameters may be attributed to the presence of naturally occurring organic substances that promotes cell expansion and division during these growth stages. stages (Finnie and Van Staden, 1985). Although, despite recorded numerical increases, application of the extract became pronounced at later groeth stages.

Plant nutrient uptake revealed that treatment applications significantly enhanced nitrogen, phosphorus, and potassium absorption within the plant tissues compared to the control. The highest uptake was consistently observed in T, supporting previous studies about the positive effects of seaweed extract on nutrient absorption efficiency (Aldworth and Van Staden, 1987; Mohan et al., 1994). This improved nutrient uptake may be associated to the presence of

bioactive compounds in the extract that stimulate nutrient utilization and transport within the plants (Blunden, 1991). Nevertheless, high amounts such as T4 resulted in reduced uptake, suggesting that excessive rates may negatively influence plant performance (Mojica, 2010).

Result findings suggest that utilization of seaweed extract may improve plant performance thereby can be use a supplement for enhancing growth of horticultural crops auch as Chinese kale. Among the treatments, T2 or application at 10 mL per L of water proved to be the most effective. It is therefore wise to avoid excessively sandy soil media to enhance both nutrient and water uptake. Further studies on heavy metal screening are highly recommended for consumer safety. Other research may also explore pure extract alone without molasses to evaluate individual effects determine the specific contribution of seaweed-derived nutrients and bioactive compounds to plant growth and development.

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Conflicts of interest

The authors declare no conflict of interest.

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