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Comparative performance of irradiated and non- irradiated carrageenan-based foliar fertilizers on the growth, yield, and pest incidence of pechay (*Brassica rapa L.*)

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ABSTRACT. This study evaluated and compared the effects of supplementing irradiated and non-irradiated carrageenan-based foliar fertilizers with the same source, *Kappaphycus alvarezii*, on the growth, yield, and pest incidence of pechay (*Brassica rapa L.*) plants, as well as to determine their profitability. The VitalGro Carrageenan Plant Growth Promoter (CPGP) and the Kappaphycus Drippings Foliar Fertilizer (KDFF) were used as the irradiated and the non-irradiated carrageenan-based foliar fertilizers, respectively. The experiment was laid out using a Randomized Complete Block Design (RCBD) with four treatments: T_1 = 0 application (negative control), T_2 = Farmer's Practice (positive control), T_3 = Farmer's Practice + VitalGro CPGP, and T_4 = Farmer's Practice + KD Foliar Fertilizer (KDFF), replicated four times. Analysis of Variance (ANOVA) was used to analyze the data with the Duncan Multiple Range Test (DMRT) to compare differences in treatment means. Profitability was determined using cost and return analysis. Supplementation of VitalGro CPGP and KDFF exhibited comparable results in increasing the height (p = *.000*) and number of leaves (p = *.008*) of pechay plants. Various insect pests were detected throughout the experimentation, but the most damaging pest was the cabbage webworm (*Crocidolomia binotalis*) which was found to be highest (p = *.000*) in plants treated with the non-irradiated KDFF. While no pest repelling effects were observed in both the carrageenan-based foliar fertilizers, plants supplemented with VitalGro CPGP were noted to be the most tolerant and gained the highest Yield (p=*.001*) despite pest attack, thereby achieving the highest return of investment (ROI) at 94.86%. The use of VitalGro CPGP as a supplement to the farmer's practice is therefore recommended for farmers hoping to increase production, revenues, and profit.

Keywords: *Growth promoter, seaweed, soil fertility management*

INTRODUCTION

Pechay (*Brassica rapa L.*) is one of the most common leafy vegetables cultivated in the Philippines. Its immature but fully expanded tender leaves and the succulent petiole are ideally eaten in many food preparations (Jimenez et al., 2016). It is one of the vegetables considered an excellent source of revenue for farmers (Gonzaga et al., 2017), especially those with limited space in their backyard, adopting the style of verticalgardeningusingrecycledplasticbottles (Prado and Sampaga, 2013). In 2020, the country produced about 98,895.20 MT of pechay from 10,812.87 hectares of area planted. Of this, 182.05 MT from 45.50 hectares came from Davao Oriental (Philippine Statistics Authority, 2021). In Mati City, this is popularly grown to support the government initiative as it strengthens its Green Communities (GreenCom) Program that started last 2014 (Perez, 2017). Given its importance in food security, health, and economic benefits, optimizing its Yield has always been the primary goal of producing this crop. Thus, fertilizers are applied to help crops achieve their maximum growth and yield performance while improving soil's nutrient status and quality (Sharma and Chetani, 2017). Its type and Application are essential in crop production (Bandera, 2020).

The employment of pest management is another essential technique in making crop production sustainable. In the brassica family, insect pests such as cabbage webworms, diamondback moths, cutworms, etc., have become a perennial problem, especially in pechay production (Squarespace, 2017). Thus, aside from the goal of boosting production through appropriate soil fertility management, producing highly effective plant protection products that are readily available and environmentally safe for wildlife and consumers is something to look forward to (Mochiah et al., 2011).

Many technologies have been developed to help farmers boost their Yield, thereby increasing their income. One recent technology was the Application of seaweeds, particularly carrageenan, as a foliar fertilizer. Carrageenan, a food additive and a thickening agent extracted from seaweeds, particularly the *Kappaphycus alvarezii* (red seaweed), has been tested as a plant food supplement which gave positive results (Abad et al., 2018).

In 2014, the Department of Science and Technology - Philippine Nuclear Research Institute (DOST-PNRI) subjected carrageenan to radiation using an electronic beam to break it into smaller particles making it readily available and easily absorbable by plants. Radiation-degraded carrageenan was found to be a valuable plant growth promoter (Abad, 2005). Results from field trials indicated that irradiated carrageenan could increase rice yields by 25-30% and were reported to repel harmful rice insect pests and diseases such as blight and infestation caused by the tungro virus (Eusebio, 2016). It has also boosted mung bean production with an increased yield of 0.49t/ha (Gatan and Gatan, 2019). The product is now called "VitalGro Carrageenan Plant Growth Promoter" and is currently commercially available.

In contrast, the Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST) in Davao Occidental developed an organic foliar fertilizer from the drippings of *Kappaphycus alvarezii* branded as "Kappaphycus Drippings Foliar Fertilizer" (KDFF) which is also now commercially available (Aragana, 2016). The process involves washing carrageenan with seawater, exposing it to direct sunlight, and allowing it to drip. Application of KDFF was reported to increase the Yield of rice (Geroche et al., 2022) as well as enhance the vegetative growth, particulalr leaf stalk and leaf count, of carrots (Guinita, 201). It has also provided an alternative source of livelihood and additional income to fisherfolks engaged in seaweed farming in Davao. While there are mounting reports on the effectiveness of these carrageenan-based foliar fertilizers in increasing the Yield of various crops, their effects on insect pests have not yet been exhaustively investigated. In addition, any effective technology can only be acceptable to farmers if they have economic returns. Thus, this study was conducted to a). compare the effects of irradiated and non-irradiated carrageenan-based foliar fertilizers on the growth and yield performance of pechay plants; b). determine their possible repelling effects on the insect pests of the crop and c). estimate the cost and return of supplementing these foliar applications to the existing farmer's practice of pechay production in Mati City, Davao Oriental.

METHODOLOGY

Location of study area

This study was conducted at Davao Oriental State University Demonstration Farm located at Marfori, Barangay Don Enrique Lopez, Mati City, Davao Oriental, from December to January 2022.

Research Design

This experiment was laid out using a randomized complete block design (RCBD) with four (4) treatments and four (4) replications. The treatments were the following: T_1= 0 application (negative control); T_2 = Farmer's Practice (positive control); T_3= Farmer's Practice + VitalGro Carrageenan PGP and; T_4 = Farmer's Practice + KD Foliar Fertilizer. The negative control served as the baseline of the experiment providing a point of comparison among the different treatments and showing the capacity of the bare soil to supply the needed plant nutrients. The positive control, on the other hand, served as the reference point in comparing the two different foliar fertilizers in improving the growth and yield performance of pechay plants. The total area of the field was 104 m2 (6.5 m x 16 m), divided into four blocks representing the four replications. A distance of 1 meter between blocks and 0.5 meter between plots within the block was employed, with each plot measuring 1 m x 3 m. Each plot contained 64 plants with a planting distance of 20 cm x 20 cm.

Procurement and Preparation of Materials

The VitalGro CGCP was used as the irradiated carrageenan-based foliar fertilizer acquired from a commercial distributor, while for the non-irradiated carrageenan-based foliar fertilizer, the KD Foliar Fertilizer (KDFF) was used, which was acquired from the Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST). The Pavo variety of pechay variety was used in this study.

Cultural Management

The field had undergone soil tillage to remove the weeds and cultivate the soil to make plots suitable for planting. Each $3m^2$ plot was applied with 2 kilograms of chicken dung except for Treatment one. The seeds were first sown in the seedling trays using a mixture of 50% humus and 50% soil as the planting medium and allowed to grow inside the nursery. Transplanting was done 14 days after seed germination. Watering was done uniformly for all the treatments throughout the study period. The plots were kept weed-free. The plants were harvested by hand- pulling 25 days after transplanting (DAT).

Fertilizer Application/Application of Treatments

This study followed the farmer's practice of applying diluted urea (46-0-0) in the soil at a rate of 100 kg/ha in three splits. The rate of Application of Vitalgro CPGP was 3 L/ ha (6.25 ml/ L of water) based on the results of farmers' trials made by Vitalgro (Jezil et al., 2021). A 9L/ha (20 ml/ L water) for KD Foliar Fertilizer was also used, as provided in the product label. Both treatments were applied through foliar spraying three days from transplanting (DAP), then followed weekly at 7, 14 until 21 DAT.

Data Analysis

There were ten randomly selected plants per plot that were used as samples. These plants were taken from the inner rows of the plot and were assessed to fulfill the needed data: plant height (cm) and the number of leaves as growth parameters; non-marketable weight (kg), marketable weight (kg), and biomass percentage for Yield and yield components; mean insect population for observation on insect population dynamics and pest repelling effects. Using a ruler, plant height was measured from the base of the plant to the tip of the highest leaf, and the average from the 10 random plants was computed. For the marketable weight, 10 random plants that were visually presentable with no deformities, with less to no significant damage/s in the foliage and petiole, and exhibited the right size were selected, weighed using a digital weighing scale, and averaged. Yield was based on the average actual Yield per treatment and then converted into per hectare basis. For the biomass percentage, three plants per plot were taken and weighed to get the fresh weight. The samples were then subjected to oven drying at 105 ⁰C for 2- 6 hours until they were completely dried and were weighed again using a Triple Beam Balance. Biomass percentage was then computed by dividing the dry matter weight by its fresh weight x 100. On the other hand, mean insect population refers to the average number of insect pests observed per plot from the same 10 randomly tagged plants. Visual counts were done at any time of the day, but especially early in the morning. The data gathered were subjected to Analysis of Variance (ANOVA) with the Duncan Multiple Range Test (DMRT) to compare differences between treatment means at $p \leq 0.05$. Return on investment (ROI) was calculated based on computed Yield over total production cost.

RESULTS AND DISCUSSION

Plant Height

Applying irradiated carrageenan-based VitalGro CPGP as a supplement to farmers' practice of applying urea fertilizer obtained the highest weekly mean plant height among all the treatments except for Week 2 or at 14DAT (Table 1). Nevertheless, analysis of variance (ANOVA) revealed that differences in mean plant height among treatments were not significantly different during the first two weeks (at 7 and 14DAT). On the third week (21 DAT), however, the results indicated significant differences among treatment means (*P=.01*), although post hoc analysis using DMRT revealed that Application of irradiated and non-irradiated carrageenan-based foliar fertilizer gave comparable results. Similarly, highly significant differences (*P = .001*) were also observed among the mean plant height of the four treatments during the fourth or final week. While plants

Table 1. The weekly mean of plant height of pechay treated with Irradiated and Non-irradiated Carrageenan- Based Foliar Fertilizers at 7, 14, 21, and 25 days after transplanting (DAT).

Treatments	Plant Height (cm)			
	7 DAT	**14 DAT**	**21 DAT**	**25 DAT**
T1 - No Application (-Control)	13.52	15.55	26.53^{c}	31.11^{c}
T2 - Farmer's Practice (+ Control)	13.48	16.10	31.14^{b}	34.82^{b}
T3 - Farmer's Practice + (Irradiated) VitalGro Carrageenan PGP	14.03	16.27	33.10^{a}	37.74^{a}
T4 - Farmer's Practice + (Non-Irradiated KD Foliar Fertilizer	13.62	16.67	31.68^{ab}	36.45^{ab}
***p*- value**	**0.89**	**0.79**	**0.01****	**0.00****
CV	**8.40%**	**10.20%**	**11.10%**	**8.70%**

Means followed by the same letter(s) in the same column are not significantly different using Duncan's test.

treated with VitalGro CPGP attained the highest mean plant height, this is considered not significantly different from those treated with KD foliar fertilizer. In addition, the application of urea gave comparable mean plant height with those applied with KD Foliar fertilizer.

This implies that applying synthetic fertilizer like urea to pechay plants, as practiced by farmers, could improve the growth of plants, specifically, height. This was also observed by Jimenez et al. (2021) that fertilizing urea can make the plant reach its average optimum height of 30 cm. However, the results also suggest that supplementing carrageenan-based foliar fertilizers in irradiated or non-irradiated forms could further enhance plant height, coinciding with the study of Abad et al. (2016) and Argana (2016), which reported an increase in pechay height when supplemented with irradiated carrageenan and KD Foliar Fertilizer, respectively.

Number of Leaves

The mean of the number of leaves of pechay plants applied with different treatments showed no significant differences from 7 DAT to 21 DAT but was found to be highly significant (*P= 0.01*) at 25 DAT (Table 3). Plants supplemented with non-irradiated KD Foliar fertilizer recorded the highest average number of plant leaves. However, statistically comparable with those supplemented with the irradiated VitalGro CPGP. On the other hand, the farmer's practice (T_2) was also considered statistically similar to the result of the irradiation, while both of the controls presented comparable results in terms of the mean number of leaves.

The results suggest that supplementation of irradiated and non-irradiated carrageenan-based foliar fertilizers effectively increases the number of leaves of pechay plants, especially the Application of Urea + KDFF, which obtained a significant result from the controls. This is consistent with the study of Guinita (2019), which showed that a higher application dosage of KD Foliar fertilizer translated to an increased number of leaf stalks and leaves in carrots and attributed the result to KD's nutrient composition of nitrogen, phosphorus, and potassium, in which the nitrogen had greater percentage. Greater nitrogen could lead to an increase in the leaf cells and cell size of the leaf, eventually leading to an increase in leaf production (Elhindi et al., 2015).

Similarly, a study by Bi et al. (2011)

Table 2. The weekly mean of the number of leaves of pechay treated with Irradiated and Non- irradiated Carrageenan- Based Foliar Fertilizers at 7, 14, 21, and 25 days after transplanting (DAT).

Treatments	**Mean Number of Leaves**			
	7 DAT	**14 DAT**	**21 DAT**	**25 DAT**
T1- No Application (-Control)	5.75	6.50	9.00	9.50c
T2- Farmer's Practice (+ Control)	5.5	6.75	9.75	0.25bc
T3- Farmer's Practice + (Irradiated) VitalGro Carrageenan PGP	6.00	6.50	10.25	11.00ab
T4- Farmer's Practice + (Non-Irradiated KD Foliar Fertilizer	5.50	6.75	9.25	11.25a
p- value	**0.52**	**0.91**	**0.38**	**0.01****
CV	**11.40%**	**11.20%**	**11.80%**	**8.50%**

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indicated that κ-carrageenan can increase the number of leaves of some plants, such as chickpeas and corn. In tobacco spray, the Application of κ-carrageenan was found to increase the cell number (not the cell size) of the plants, which also increased the plant's growth and cell division (Castro et al., 2012). Carrageenan from red seaweed can improve plant growth parameters by regulating some metabolic processes, which include: photosynthesis, ancillary pathways, cell division, purine and pyrimidine synthetic pathways, as well as metabolic pathways involved in nitrogen and sulfur assimilation (Shukla et al., 2016).

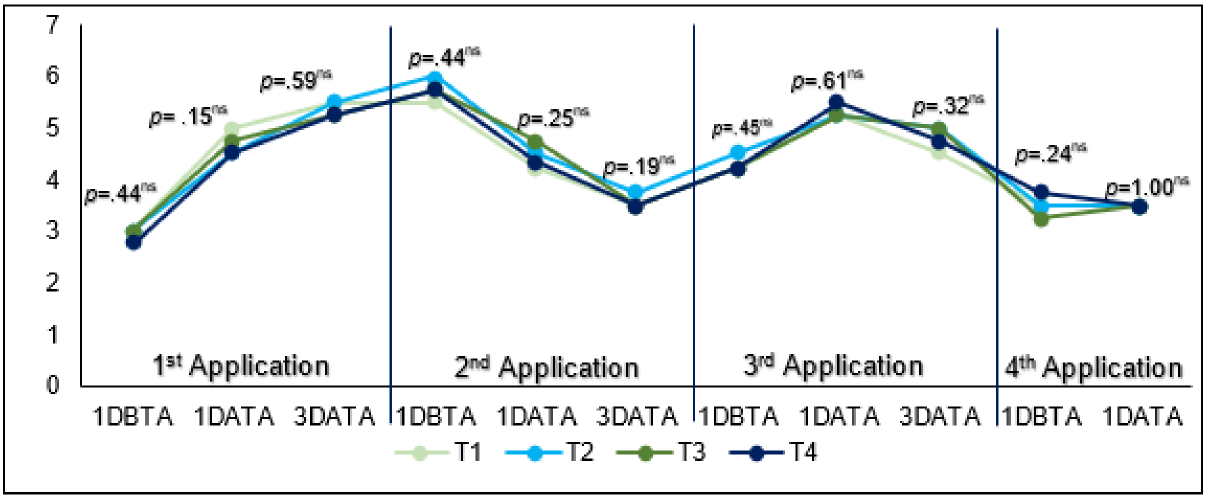

Figure 1. Mean Population of flea beetles observed per plot based on 10 sample plants/ plot as affected by different carrageenan- based foliar fertilizers. ns - Not Significant, DBTA – Day before treatment application, DATA – Day after treatment application.

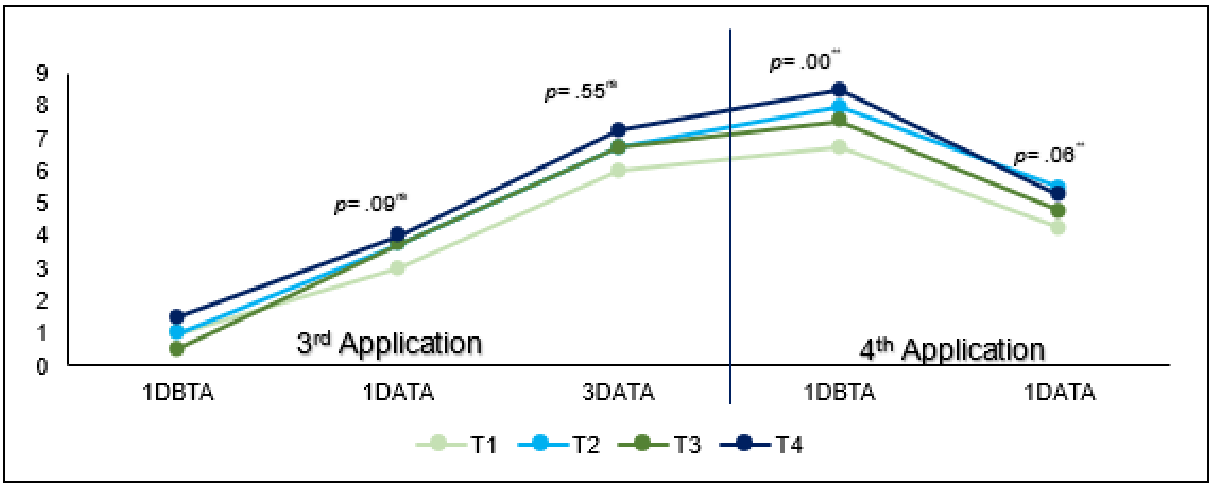

Figure 2. Mean Population of cabbage webworms observed per plot based on 10 sample plants/ plot as affected by different carrageenan- based foliar fertilizers. Means followed by the same letter(s) in the same column are not significantly different using Duncan's test.

Insect population dynamics and pest repelling effects

The most populous insect present and consistently visible throughout the experimentation were the flea beetles, which were noted to be not significantly affected by any of the carrageenan-based foliar fertilizer applications. During the first week of the experimentation, the exponential growth of its population was noticeable but dropped in the following week. On the third Application, another rise in its population was observed but again dropped during the final week (Figure 1). According to Olson and Knodel (2002), this type of insect could be affected by cool, windy, and wet weather. This might explain the random drops in its population throughout the experimentation period.

The most damaging pest to affect pechay was the cabbage webworm (*Crocidolomia binotalis*). Compared to the flea beetles, which were already noticeable at the start of the study, the earliest detection of cabbage webworms happened to be at the onset of the third week. Plants treated with KDDF were found to contain the highest mean population of cabbage webworms, but differences among treatment means were noted to be not significantly different except on the day before the fourth treatment application (1 DBTA), which gave a highly significant result (Figure 2). The significantly high insect density during the experiment's later stage coincided with the crops' most vigorous vegetative stage when there was greater potential for damage. This was also considered the most destructive period for cabbage webworms.

Some other arthropods, like brown and green grasshoppers, katydids, small orange beetle, cutworm, and green grass pyrgomorph, were also noticeable on the different treatments, but their populations were observed to be fewer than the flea beetles and cabbage webworm. Additionally, only one spider was also detected to be present in the field throughout the experimentation (Figure 3).

Based on these observations, the Application of either irradiated or non-irradiated carrageenan-based foliar fertilizers generally appears to exhibit no repellency against various insect pests of pechay. This is similar to the findings of Sangha et al. (2011), indicating that carrageenan has no suppressive effects on the growth and development of cabbage looper (*Trichoplusia ni*) under an amended artificial diet bioassay. It was also observed that neither of the treatments caused detrimental effects on the beneficial arthropod spider. Moreover, other pest attacks such as nematodes, fungi, and/or any other pathogens are not included in the observations of the study.

Marketable, Non- marketable and Total weight of Pechay

Among the four treatments, the heaviest non-marketable weights were found in plants supplemented with KDFF while plants treated with VitalGro CGCP exhibited the highest marketable weight and proved to be significantly higher than all the other

Table 3. Marketable, non-marketable and total weights of pechay based on 10 randomly tagged sample plants as affected by different carrageenan- based foliar fertilizers

Treatments	Weight (kg)		
	Non-marketable	Marketable	Total
T1- No Application (-Control)	0.11bc	1.55d	1.665d
T2- Farmer's Practice (+ Control)	0.14a	1.9bc	2.035bc
T3- Farmer's Practice + (Irradiated)			
VitalGro Carrageenan PGP)	0.12b	2.25a	2.3725a
T4- Farmer's Practice + (non- irradiated			
KD Foliar Fertilizer	0.14a	2.05b	2.1925b
***p*- value**	**0.42**	**0.00**	**0.00**
CV	**11.90%**	**14.3%**	**13.6%**

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treatments. In terms of their total weight, the result was also significantly highest in plants with VitalGro CGCP, followed by KDFF, which was also statistically comparable to that of farmer's practice (T_2). The lowest weight was found in Treatment 1 (Table 3).

The high amount of non-marketable weights in Treatments 2 and 4 can be explained by the high mean population of insect pests, particularly the cabbage webworms present in these treatments. However, these pests did not cause major damage to the pechay plants supplemented with VitalGro CPGP. The performance of KDFF also did a better result than that of the farmer's practice, but not as effective as the irradiated ones implying that pechay plants treated with irradiated carrageenan have exhibited tolerance as they still produce a significant marketable weight despite the pests' attack (Figure 4). Tolerance is the plant's ability to withstand an herbivore injury through growth and compensatory physiological processes (Koch et al., 2016). This is supported by the study of Sanga et al. (2011), indicating that carrageenan can induce plant defense against insect pests, aside from pathogens, due to its polysaccharide content. Mousavi et al. (2017) also stated that k- carrageenan helps induce the growth parameters and the activation of the plant's enzymatic defense system. This makes carrageenan a natural biostimulator for protecting plants against *Cuscuta campestris.*

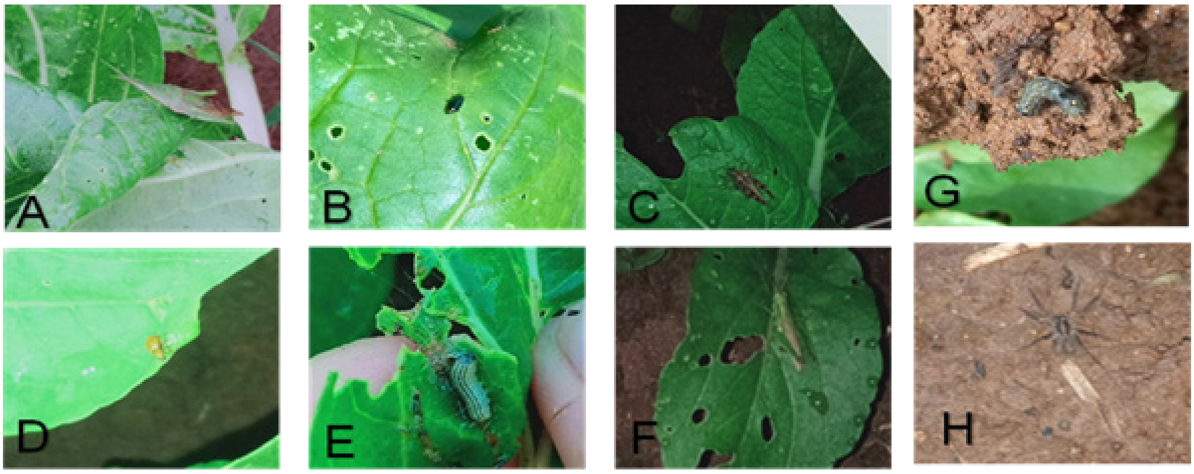

Figure 3. Insect pests such as Green Grass pyrgomorph (A), Flea Beetles (B), Brown Grasshopper (C), Soldier Orange Beetles (D), Cabbage Webworm (E), Green Grasshopper (F), Cutworms (G), and beneficial arthropods like Spider (H) were observed in the field during the experimental period.

Marketable, Non- marketable and Total weight of Pechay

Among the four treatments, the heaviest non-marketable weights were found in plants supplemented with KDFF while plants treated with VitalGro CGCP exhibited the highest marketable weight and proved to be significantly higher than all the other treatments. In terms of their total weight, the result was also significantly highest in plants with VitalGro CGCP, followed by KDFF, which was also statistically comparable to that of farmer's practice (T2). The lowest weight was found in Treatment 1 (Table 3).

The high amount of non-marketable weights in Treatments 2 and 4 can be explained by the high mean population of insect pests, particularly the cabbage webworms present in these treatments. However, these pests did not cause major damage to the pechay plants supplemented with VitalGro CPGP. The performance of KDFF also did a better result than that of the farmer's practice, but not as

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On the other hand, the high marketable weight of pechay plants treated with Vitalgro CGCP could be attributed to the combined effect of enhanced growth factors like plant height and the number of leaves and the relatively low mean insect population (compared to plants applied with KD foliar fertilizer or those treated with standard farmer practice of urea application) which is then translated into low plant damage or low non-marketable plants. This finding is similar to the study of Antonio et al. (2019) that using irradiated carrageenan plant growth promoters in passive hydroponics systems significantly increased the growth parameters of Kale (*Brassica oleracea varaceplhala*) such as plant height, number of leaves, leaf width and weight, root length, plant weight, as well as its total marketable yield.

Moreover, a noted advantage of irradiated carrageenan over non-irradiated carrageenan is its absorption rate. One particular purpose of irradiating carrageenan is to lessen its particle size to make it more absorbable to plants. This suggests an explanation for the better performance of irradiated carrageenan-based foliar fertilizers than that of non-irradiated ones.

Figure 4. The marketable pechay plants of the different treatments showing some pest damage.

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The radiation-processed material from natural polymers promotes nutrient uptake causing an increase in the Yield of crops. When using irradiated carrageenan, a plant can absorb 95-98% of the essential nutrients it requires (Abad et al., 2018).

Computed Yield (kg/ha.)

The marketable weights presented in Table 7 are computed on per hectare basis from the mean Yield obtained from each treatment. T3 exhibited the highest Yield with a total of 3, 580.21 kg, followed by T_4 with 3, 240.71 kg, followed again by T_2 with 2, 777. 75 kg, and the least is from T_1 with 1, 851. 83 kg. Analysis of variance also suggests that the computed Yield of T_3 was significantly different from the rest of the treatments, while the Yield of T_4 produced a comparable result with T_3. This implies that the supplementation of carrageenan-based foliar fertilizers effectively increases the pechay yield compared to the farmer's practice.

This finding is similar to the study of Abad et al. (2016) that irradiated carrageenan was able to increase the fresh weight of pechay (2016) and an average of 20% rice yield in the different areas of the Philippines was noted to increase against the usual farmer's practice. This significant increase was due to the extensive growth in the rice root system and the rise in the number of tillers. Irradiated carrageenan was also found to be effective in increasing the yields of mung beans (Pag-Asa 21 and Kulabo) by expanding the pod length and number of seeds per pod (Gatan, 2019). On the other hand, the results also agree with the report of Argana (2016) that KDFF was able to increase the Yield of rice, baby corn, soybean, mung bean, sweet pepper, cauliflower, mango, pechay, and orchid.

Table 4. Computed yield (kg/ha) of pechay plants as affected by different carrageenan-based foliar fertilizers.

Treatments	Yield (kg/ha)
T1- No Application (-Control)	1, 851.83[d]
T2- Farmer's Practice (+ Control)	2, 777. 75[c]
T3- Farmer's Practice + (Irradiated) VitalGro Carrageenan PGP)	3, 580.21[a]
T4- Farmer's Practice + (non- Irradiated KD Foliar Fertilizer	3, 240.71[ab]
***P*- value**	**0.00**
CV	**24.6**

Means followed by the same letter(s) in the same column are not significantly different using Duncan's test.

Biomass Percentage

The biomass percentage was found to be highest in T4 (13.66%) but was also significantly comparable to the result of T3 (13.31%). Treatment 2, with 12.03%, was also statistically comparable to T3, while T1 had the lowest biomass percentage (Table 5).

Carrageenan- based foliar fertilizers are proven to be excellent in enhancing the relative dry matter of the plant. As mentioned by Gatan et al. (2019) in the study of Relleve et al. (2005), the effect of irradiated carrageenan on the biomass of potatoes was increased at 35%, and this finding supports the results of this study. Similarly, according to Bi et al. (2011), the spray applications of κ- carrageenan can increase cell division in tobacco plants leading to an increase in cell numbers, which could also affect the plant biomass. It was suggested that the oligomeric forms of carrageenan increased the plant biomass by modulating the effects

Table 5. Computed yield (kg/ha) of pechay plants as affected by different carrageenan-based foliar fertilizers.

Treatments	Biomass Percentage			
	7 DAT	14 DAT	21 DAT	25 DAT
T1 - No Application (-Control)	8.44	9.3[d]	10.8[cd]	10.38[c]
T2 -Farmer's Practice (+ Control)	9.5	11[c]	11.7[c]	12.03[b]
T3 - Farmer's Practice + VitalGro Carrageenan PGP	9.15	13.03[a]	13[ab]	13.31[ab]
T4 - Farmer's Practice + KD Foliar Fertilizer	9.3	13[ab]	13.3[a]	13.66[a]
***p*- value**	**0.22**	**0.00**	**0.03**	**0.05**
CV	**10.3%**	**14.8%**	**11.3%**	**13.2%**

Means followed by the same letter(s) in the same column are not significantly different using Duncan's test.

of the cell cycle expression regulatory proteins (Castro et al., 2012; Gonzales et al., 2013). The oligomeric form of carrageenan, which are a low molecular weight carrageenan, is proven to enhance the physiological functions of the plant (Hashmi et al., 2012; Ahmad et al., 2017; Singh et al., 2017; Naeem et al., 2019; Naeem et al., 2012).

Cost and Return Analysis

Yield and profit are the number one basis for farmers to determine which technology is adequate to adopt. Each treatment's return on investment (ROI) says that Treatment 3 can achieve as much as 94.86% of ROI. This is followed by Treatment 3 with 77.03%, Treatment 2 with 57.89%, and Treatment 1 with only 37.75% ROI. Based on the analyzed production and return, the most cost-effective is the production of pechay with the supplementation of Irradiated Carrageenan-based foliar fertilizer. This is because although the supplement has an additional cost, its return is still the highest among all the treatments.

On the other hand, the non-irradiated carrageenan-based foliar fertilizer imposed a better performance against the farmer's practice. This would also infer that irradiated carrageenan-based foliar fertilizer supplementation is an excellent technology for production, Yield, and profit improvement. Furthermore, the results of the cost and return analysis will a good basis for business purposes providing an educative background for farmers wanting to venture into business.

Table 6. Cost and return analysis in terms of production cost (per hectare and per kilogram produced and on return on investment of pechay plants applied with different treatments.

Treatments	Cost and Return Analysis		
	Production Cost (pesos)		Return on Investment (%)
	Per Hectare	Per kg. Produced	
No Application (-Control)	40, 330	21.78	37.75
Farmer's Practice (+ Control)	52, 780	19	57.89
Farmer's Practice + VitalGro Carrageenan PGP	55, 120	18.4	94.86
Farmer's Practice + KD Foliar Fertilizer	54, 919	16.95	77.03

CONCLUSION AND RECOMMENDATION

The supplementation of carrageenan-based foliar fertilizers effectively enhanced the growth and Yield of bittergourd plants. Both VitalGro CPGP and KDFF exhibited comparably better growth performance than the farmer's practice in terms of plant height (*p=.05*) and mean number of leaves (*p=.01*). Various insect pests were detected in all the treatments indicating that both irradiated and non-irradiated forms exhibited no pest-repelling effects. The most destructive pest was the cabbage webworms (*Crocidolomia binotalis*), which were the highest (*p=.001*) in plants treated with non-irradiated KDFF. In contrast, plants applied with irradiated VitalGro displayed some level of tolerance to insect pests as manifested by low pest damage and thereby obtaining the highest Yield of 3 580.21 kg/ha (*p=.001*) and the highest return of investment (ROI) with 98.86% The small molecular size of the irradiated foliar fertilizer, which led to its high absorption rate, played a vital role in improving its performance, especially in enhancing the yield factor and plant tolerance against insect attacks.

Hence, the use of VitalGro CPGP as a supplement to the farmer's practice is therefore recommended for farmers hoping to increase production, revenues, and profit. On the other hand, conducting the same study is also recommended on other economically important crops in the locality to find out the possible effects of carrageenan-based foliar fertilizers on these crops.

REFERENCES

Abad L.V., Dean, G.F.O, Magsino G.L., Dela Cruz R.M.M, Tecson M.G., Abella M.E.S., Hizon. M.G.s. (2018). Semi-commercial scale production of carrageenan plant growth promoter by E-beam technology. *Radiation Physics and Chemistry,* 143:53-58

Abad, L.V., Aurigue, F.B., Relleve, L.S., Montefalcon, D.R.V., Lopez, G.E.P. (2016). Characterization of low molecular weight fragments from gamma irradiated κ-carrageenan used as plant growth promoter. *Radiation Physics and Chemistry,* 118, 75–80. doi:10.1016/j.radphyschem.2015.03.001

Abad, L.V., Aranilla, C.T., Relleve, L., Dela Rosa, A.M. (2005). Radiation processing of carrageenan using electron beam. (JAERI-Conf--2005-005). *Kume, Tamikazu* (Ed.). Japan

Agloslos, M., Regencia, M., Arcilla, F. (2021). Effects of vermicomposts produced from cow dung, saw dust and shredded paper on the growth rate and yield of Chinese Pechay (*Brassica rapa*). *IAMURE International Journal of Ecology and Conservation*, 34(1):36-49.

Antonio, T., Bayla, J., Sace, C., and Aurique, F. (2019). Kale (*Brassica oleracea varaceplhala*) production using irradiated carrageenan plant growth promoter in passive hydroponics systems. *Philippine Journal of Crop Science (Philippines)*, (44), 97-98. ISSN : 0115-463X.

Bi, F., Iqbal, S., Arman, M., Ali, A., and Hassan, M. U. (2011). Carrageenan as an elicitor of induced secondary metabolites and its effects on various growth characters of chickpea and maize plants. *J. Saudi Chem. Soc.* 15, 269–273. doi: 10.1016/j.jscs.2010.10.003

Castilla, D., Embalzado, H., Morre, J., and Salcedo, A. (2022). Mulched ipil-ipil (*Leucaena leucocephala*) leaves as a growth enhancer for pechay (brassica rapa) plant. *International Research Journal of Modernization in Engineering Technology and Science,* 4(6). 988-993. e-ISSN: 2582-5208

Castro, J., Vera, J., González, A., Moenne, A. (2011). Oligo-carrageenans stimulate growth by enhancing photosynthesis, basal metabolism, and cell cycle in Tobacco plants (var. Burley). *Journal of Plant Growth Regulation*, 31(2), 173–185. doi:10.1007/s00344-011-9229-5

Elhindi, K., El-Hendawy, S., Abdel-Salam, E., Elgorban, A., Ahmed, M. (2015). Impacts of fertigation via surface and subsurface drip irrigation on growth rate, yield and flower quality of Zinnia elegans. *Bragantia,* 75(1), 96–107. doi:10.1590/1678-4499.176

Eusebio, J.E. (2016). Carrageenan as plant food supplement boosts rice productivity. In: Bhag Mal, Shyam Sunder Singh and Raghunath Ghodake. 2017. *Expert Consultation on Best Practices in Agri-food Innovations in Asia and the Pacific.* Taichung, Taiwan; 1-3 November 2016. 144 p.

Gatan, M.G.B., Gatan, M.T. (2019). Improved integrated crop management system of mungbean (*Vigna radiata linn*) production in Central Luzon. *Recoletos Multidisciplinary Research Journal,* 7(2), 1–13. https://doi.org/10.32871/rmrj1907.02.01

Gatan, M.B., Montefalcon, D.V., Aurigue, F.B., and Abad, L.V. (2019). Effect of Radiation- modified Kappa-carrageenan on the Morpho-agronomic characteristics of Mungbean [*Vigna radiata* (L.) R.Wilczek]. *Philippine Journal of Science.* 149 (S1): 135-143.

Geroche, J.N., Caballero, G.L. Tuyac, R.O. (2022). Effects of Kappaphycus Drippings (KD) foliar fertilizer on the growth and yield performance of rice. *American Journal of Agricultural Science, Engineering, and Technology* (AJASET) 6(3):51-56.

Gonzaga, Z.C., Capuno, O.B., Labonite, M.A., Lonzaga, E.D.A., Napuran, N.F.M., Sarco, A.A. (2017). Increasing pechay (*Brassica rapa L. ssp. chinensis)* production through suitable seedling establishment under two cultivation systems in the Southern Philippines. *Annals of Tropical Research*, 39:129-136. doi: 10.32945/atr39sb10.2017

González, A., Gutiérrez-Cutiño, M., and Moenne, A (2014). Oligo-carrageenan kappa-induced reducing redox status and increase in TRR/TRX activities promote activation and reprogramming of terpenoid metabolism in Eucalyptus trees. *Molecules,* 19, 7356–7367. doi: 10.3390/molecules19067356

Guinita, C.R. (2019). Growth of carrots (Daucus carota vari. Kuroda) Supplied with different levels of Kappaphycus alvarezii drippings delivered through subsurface drip irrigation under grennhouse structure. *International Journal of All Research Writings,* 1(4):73-79.

Hashmi, N., Khan, M.M.A., Moinuddin, Idrees, M., Khan, Z.H., Ali, A., Varshney, L. (2012). Depolymerized carrageenan ameliorates growth, physiological attributes, essential oil yield and active constituents of Foeniculum vulgare Mill. *Carbohydrate Polymers,* 90(1):407-412.

Jimenez, E.F., Mariano, J.S., Ferrer, M.J., De Leon, V.E.R.E.N.A. (2021). Pechay production guide.

Koch, G., Chapman, K., Louis, J., Heng-Moss, T., and Sarath, G. (2016). Plant Tolerance: A Unique Approach to Control Hemipteran Pests. *Frontiers in Plant Science,* 7. DOI:10.3389/fpls.2016.01363

Mochiah, M.B., Banful, B., Fening, K.N., Amoabeng, B.W., Offei Bonsu, K., Ekyem S., Braimah, H., Owusu-Akyaw, M. (2011). Botanicals for the management of insect pests in organic vegetable production. *Journal of Entomology and Nematology,* 3(6): 85-97.

Mousavi, E., Nasibi, F., Kalantari, K., Oloumi, H. (2017) Stimulation effect of carrageenan on enzymatic defense system of sweet basil against Cuscuta campestris infection. *Journal of Plant Interactions,* 12:1, 286-294, DOI: 10.1080/17429145.2017.1341560

Naeem, M., Idrees, M., Aftab, T., Khan, M.M.A., Moinuddin, Varshney, L. (2012). Depolymerised carrageenan enhances physiological activities and menthol production in *Mentha arvensis* L. *Carbohydrate Polymers,* 87(2):1211-1218.

Naeem, M., Idrees, M., Aftab, T., Alam, M.M., Khan, M.M.A., Uddin, M., Varshney L. (2015). Radiation processed carrageenan improves plant growth, physiological activities, and alkaloids production in *Catharanthus roseus* L.", *Advances in Botany,* vol. 2015, Article ID 150474, 11 pages, 2015. https://doi.org/10.1155/2015/150474

Naeem, M. Nabi, A., Tariq Aftab, T., Masroor, M., Khan, A. (2019). Oligomers of carrageenan regulate functional activities and artemisinin production in Artemisia annua L. exposed to arsenic stress. *Protoplasma*. https://doi.org/10.1007/s00709-019-01475-y

Olson, Denise L., Knodel, J.J. (2002). Crucifer flea beetle biology and integrated pest management in canola. N*DSU Extension Service*.

Perez, A. (2017). Mati Promotes Backyard Garden. SUNSTAR. Retrieved from https://www.pressreader.com/philippines/sunstar davao/

Philippine Statistics Authority (2021). Other Crops: Area Planted/Harvested, by Region and by province, by Semester, 2010-2020. Retrieved from https://openstat.psa.gov.ph/

Philippine Statistics Authority (2021). Other Crops: volume of production, by region and by province, by quarter and semester, 2010-2020. Retrieved from https://openstat.psa.gov.ph/

Prado, A. Sampaga, L. (2013). Response of pechay (Brassica rapa) to organic fertilizer under DMMMSU-NLUC condition, La Union, Philippines. E –*International Scientific Research Journal,* 5 (3), 258- 261. ISSN 2094 – 1749

Sangha, J.S., Khan, W., Ji, X., Zhang, J., Mills A.A.S. (2011). Carrageenans, sulphated polysaccharides of red seaweeds, differentially affect *Arabidopsis thaliana* resistance to *Trichoplusia ni* (Cabbage Looper). *PLoS ONE* 6(10): e26834. doi:10.1371/journal.pone.0026834

Schreinemachers, P., Simmons, E.B., Wopereis, M.C.S. (2016). Tapping the economic and nutritional power of vegetables. *Review Article: Global Food Security,* 16:36-45.

Shukla, Pushp S., Borza, Tudor, Critchley, Alan T. Prithiviraj, Balakrishnan. (2016). Carrageenans from red seaweeds as promoters of growth and elicitors of defense response in plants. *Frontiers in Marine Science*, 3. DOI:10.3389/fmars.2016.00081

Squarespace (2017). Pechay IPM factsheet. Retrieved from http://static1.squarespace.com/

Ubaub, L. and Poblacion, L. (2016). Vesicular- arbuscular mycorrhizal Fungi and seaweed extract for the control of fusarium wilt (*Fusarium Oxysporum F. Sp. Cubense* Tr4) of potted 'cavendish' banana under nursery condition. *International Journal of Scientific Research in Environmental Sciences,* 4(7), pp. 0208-0218. DOI: http://dx.doi.org/10.12983/ijsres-2016-p0208-0218