Asian Journal of Agricultural and Horticultural Research

Volume 10, Issue 4, Page 322-334, 2023; Article no.AJAHR.104260
ISSN: 2581-4478

Enersol Promotes Growth and Yield Performance of Pechay (*Brassica rapa* L. var. *chinensis* (L.) Hanelt)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAHR/2023/v10i4274

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/104260

Original Research Article

Received: 01/06/2023
Accepted: 04/08/2023
Published: 12/08/2023

ABSTRACT

This study presents the results of a field bio-efficacy evaluation to assess the impact of Enersol® LDG, a mineral fertilizer containing leonardite and humic acid, on the growth and yield of pechay (*Brassica rapa*) in Puypuy, Bay, Laguna, Philippines. In pechay production, there is a need for a plant food supplement that facilitates immediate nutrient absorption. Leonardite-based products have been used to improve soil properties and to help plants withstand biotic and abiotic stresses. Leonardite is an important raw material in the manufacture of commercial products rich in humic and fulvic acids. An experiment in a randomized complete block design with three replications was

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conducted, with different combinations of Enersol® LDG and inorganic fertilizer applied basally at seed sowing. Results showed that the combination of Enersol® LDG and inorganic fertilizer significantly increased the total fresh yield of pechay compared to other treatments. However, reducing the amount of inorganic fertilizer resulted in lower yields, regardless of the Enersol® LDG application rate. The marketable yield and percent marketable yield were also significantly higher in plants treated with Enersol® LDG and inorganic fertilizer combinations compared to the control and Enersol® LDG alone. Based on these findings, it can be concluded that Enersol® LDG, when combined with inorganic fertilizer, significantly enhanced the growth, and yield of pechay. Further research is recommended to explore optimal dosage and application methods for maximizing pechay production using Enersol® LDG.

Keywords: Enersol; humic acid; leonardite; low dust granules, pechay.

1. INTRODUCTION

Pechay (*Brassica rapa* L. var. *chinensis* (L.) Hanelt) group cultivars, is an erect, biennial herb, cultivated as an annual about 15–30 cm tall in vegetative stage. Leaves are ovate arranged spirally and spreading, while the petioles are enlarged and grow upright forming a near-cylindrical bundle [1]. The inflorescence is cone-shaped with pale yellow flowers. The seeds are 1 mm in diameter and are somewhat maroon in color [2]. Pechay is an important component of Filipino food, such as “puchero”, “ginisa” and “nilaga.” It is a green leafy vegetable rich in calcium and other important nutrients. Its nutritional values are made up of 93.0 g water, 1.7 g protein, 0.2 g fat, 3.1 g carbohydrates, 0.7 g fiber, 0.8 g ash, 2.3 g β-carotene, 102.0 mg calcium, 53.0 mg vitamin C, 2.6 mg iron,46.0 mg phosphorous, and an energy of 86.0 kJ. Pechay is used for its immature, but fully expanded tender leaves [3]. The succulent petioles are used as main ingredient for soup and stir-fried dishes, while its green petioles and leaves are also used as garnish in Chinese cuisine [4,1].

Pechay is one of the top twenty vegetables and an important source of food globally, according to the Food and Agricultural Organization (FAO). According to Magbalot-Fernandez [5], the country’s Chinese pechay production slightly decreased by 0.95% in 2017, from approximately 86.3% of the country’s total *B. chinensis* production comes from the Cordillera Administrative Region, while Central Visayas comes next with a 7.0% share. The remaining 6.7% comes from a combined share from Northern Mindanao, Davao Region, and the rest of the country [6]. Thus, the root of this type of changes are being investigated.

Fertilizer application using either inorganic or organic fertilizer sources is one of the most common cultural management practices in vegetable production [7]. According to Lampkin (1990) as cited by Masarirambi (2010), the commercial and subsistence farming has been and is still relying mostly in the use of inorganic fertilizers for growing crops because they are easy to use, quickly absorbed and utilized by crops. Pechay is a short duration crop, requiring an immediate source of nutrients. In the organic production of pechay, a plant food supplement that can assist in immediate absorption of nutrients is needed [8]. Furthermore, the continuous practice of tillage and planting on the same land every year has deleterious effects on soil texture and structure [9-12].

Several studies in using various fertilizers and foliar supplements have been conducted to determine their bio-efficiency in maximizing the growth and yield of various crops. In pummelo plants (*Citrus maxima* Merr.) the use of fertilizer from fermented banana peel, nutrition by foliar or soil fertilization with potassium was investigated by (Magbalot-Fernandez et al. [13,14]. The effect of hormones and Bio-Forge fertilizer were analyzed [15,16] in abaca (*Musa textilis* Nee) and banana (*M. paradisiaca* L.) plants. For rice (*Oryza* L.) the effect of organic-based foliar fertilizer was checked by Montifalcon and Fernandez [17]. In pechay (*B. chinensis*) the effect of organic foliar fertilizer or the stimulating effect of hormones was examined by Fernandez and Miñoza, [18], and Fernandez and Andigan [19]. Humic acid-based products have been used in recent years as a fertilizer supplement to ensure the sustainability of agriculture production. The field efficacy in enhancing the growth and yield of pechay has recently been demonstrated using a seaweed-based foliar fertilizer [8], and a potassium humate soil conditioner rich in humic acid, nitrogen, and potassium content [20].

The use of humic substances in agriculture has increased in recent years, and leonardite has been an important raw material in the manufacture of commercial products rich in humic and fulvic acids [21]. Leonardite-based products have been used to improve soil properties and to help plants withstand biotic and abiotic stresses, and its features must be understood to help farmers make better use of these products.

One of the major developments in dry humic and fulvic acid application to crops is the introduction of Enersol LDG. Made with highly concentrated leonardite, the LDG (low-dust leonardite granule) technology captures the full humic complex in a robust and virtually dust-free granule that quickly disintegrates and disperses in soil water [22]. Enersol LDG can be blended uniformly with dry fertilizers for even distribution in the field when broadcast, placed in-furrow or side dressed, with each application delivers a powerful dose of humic fulvic acid at 70 percent that is proven to increase crop yield by over 10 percent. Each application of Enersol LDG improves soil health by increasing water-holding capacity, micronutrient availability (iron, manganese, copper, zinc, calcium, and sulfur) CEC, and organic matter content. To better understand the benefits and to help farmers make better use of these products, this study was conducted with the aim of demonstrating the bio-efficacy of Enersol Low Dust Granules (LDG) on the growth and yield of pechay under farmer's field conditions, by measuring its effect in pechay's agronomic yield parameters.

2. MATERIALS AND METHODS

The trial was conducted for one season at Puypuy, Bay, Laguna Philippines from September-October 2019. An open-pollinated pechay cultivar, Pavito was used as the test crop/cultivar.

2.1 Soil Analysis

Before bed preparation, surface (0-15 cm) soil samples were randomly collected from five different points on the experimental site for physical and chemical analysis. A complete soil physical and chemical analysis was requested from UPLB ICrops Soils Laboratory. Organic matter, nitrogen, phosphorus, and potassium levels were determined while moisture and pH were also measured.

2.2 Land Preparation

The experimental field was plowed and harrowed twice in different directions. Bed preparations were done manually using spades. Plots measuring 5x2 m^2 were made. A total of 18 plots were established.

2.3 Experimental Design and Treatment Application

The inorganic fertilizer and Enersol® LDG, based on the treatment combinations, were applied basally during the seed sowing. A control treatment of no fertilizer applied was added for comparing the growth and yield enhancing effect of the fertilizer treatments. Table 1 shows the different treatments used in the bioefficacy trial. The experiment followed a randomized complete block design with three replications (Fig. 1) to eliminate variation in the experiment considering the potential spatial effects under field conditions, e.g., sunlight, fertilizer gradient, etc.

Table 1. Treatment assignments for the bioefficacy trial

Treatments	Granular Fertilization	Enersol LDG
1	Inorganic Fertilizer alone @ 8.5 bags 14-14-14 & 4 bags urea/ha	
2		1rr Enersol® @ 50 kg/ha
3	Inorganic Fertilizer @ 8.5 bags 14-14-14 & 4 bags urea/ha	1rr Enersol® @ 50 kg/ha
4	½ Inorganic Fertilizer @ 4.25 bags 14-14-14 & 2 bags urea/ha	1rr Enersol® @ 50 kg/ha
5	½ Inorganic Fertilizer @ 4.25 bags 14-14-14 & 2 bags urea/ha	2rr Enersol® @ 100 kg/ha
6	Control	

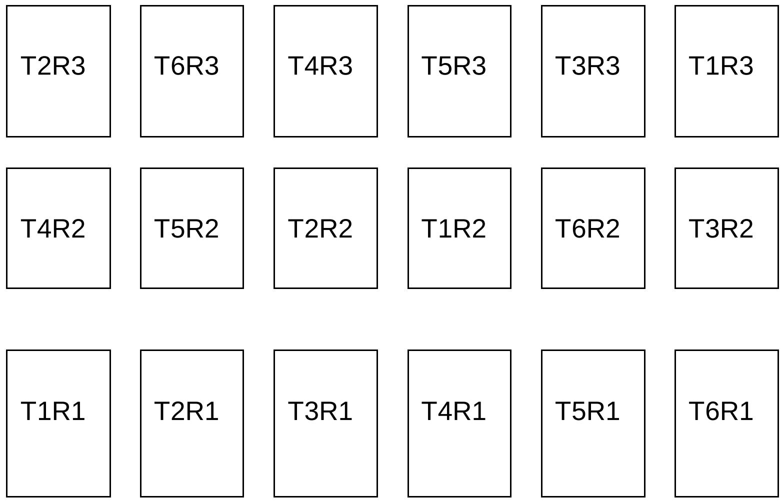

Fig. 1. Field layout using a randomized complete block design with three replications

2.4 Seed Sowing

Five rows per meter were line drilled covering the 5-meter stretch of the plot. The distance between rows is 20cm. Pechay seeds were directly sown into the soil using drill method at 1 gram per $2m^2$. The sown seeds were covered with soil. The plots were dusted with carbaryl to prevent ant foraging.

2.5 Cultural Management

The following cultural practices were implemented as needed:

2.5.1 Irrigation

Watering was done every day depending on soil moisture content and weather condition.

2.5.2 Weeding

Weeds were removed at weekly intervals to avoid competition with the crop.

2.5.3 Cultivation

Tilling the soil was done to aerate the soil and to control some weed pests.

2.5.4 Disease Control

No disease was observed in the experimental plants

2.5.5 Insect Pest Control

Insect infestation was managed by applying insecticides appropriate to the target insect pest.

2.6 Harvesting

The pechay plants were harvested ~28 days after planting. The harvested plants were sorted into either marketable or non-marketable. Non-marketable yield was classified based on plants whose leaves had holes ≥ 1 cm in diameter.

2.7 Data Gathering

Fresh weight yield of the above ground biomass plants was expressed in kg/ha and recorded. In addition, the non-marketable yield was also expressed in percent (%) of the total (marketable + non-marketable) yield. Growth parameters such as plant height, number of leaves and leaf width were also gathered from a sample of thirty plants per treatment (10/rep).

Data gathering procedure:

2.7.1 Fresh weight yield

Total yield was derived from matured plants harvested per treatment per replication. The plants for each plot were weighed using a digital weighing scale.

2.7.2 Percent marketable and non-marketable yield

This was computed after separating the marketable from non-marketable plants. Non-marketable plants are plants which are deformed, small and damaged by insects or other organisms (≥ 1 cm holes).

2.7.3 Plant height

The distance between the base of the plant and the longest/highest leaf were measured using a ruler after harvesting. A sample of ten plants per replication was measured.

2.7.4 Number of leaves

The number of mature leaves not smaller than one-inch diameter was counted. A sample of ten plants per replication was measured.

2.7.5 Leaf width

This was done by getting ten sample plants per replication and measuring the biggest leaf for each plant.

2.8 Data Analysis and Interpretation

The generated data were subjected to statistical analysis using SAS portable version. Analysis of variance and treatment mean comparison using Tukey's Studentized Range (HSD) Test were done at 5% probability level to determine whether there is a difference between the mean of all possible pairs using a studentized range distribution. This method tests every possible pair of all groups. Two-way tables were prepared to show the means and their corresponding alphabet notations. Interpretations were done by comparing each treatment, especially with the control. Conclusions and recommendations were formulated based on the results generated.

3. RESULTS AND DISCUSSION

3.1 Total Fresh Yield of Pechay

The total yield was derived from the 20 m^2 plot area and converted to fresh yield per hectare. The Analysis of Variance showed significant difference (p=.0002) among treatments. Comparing the means, have indicated that the highest fresh yield was obtained from the plants treated with the 1rr Enersol® and inorganic fertilizer. However, this is not significantly different from the plants treated with other combinations of Enersol® and inorganic fertilizer at any rate. All Enersol® and inorganic fertilizer combinations are significantly different from the plants treated with Enersol® alone and the control plants. On the other hand, the lowest fresh yield was obtained from the control plants but is not significantly different from the plants treated with Enersol® alone (Table 2).

The results revealed that pechay are responsive to inorganic fertilization in combination with Enersol®, which gave a yield increase of 6.27 and 57.87 tons per hectare over the granular inorganic fertilization alone and the control, respectively. However, lowering the amounts of inorganic fertilizer by half would give lower yields regardless of the amount of Enersol® applied. This only supported the fact that Enersol® is only effective when combined with the full dose inorganic fertilizer to which the soil enhancer product promotes efficient nutrient absorption by improving soil condition.

3.2 Number and Percent Marketable Yield of Pechay

The marketable yield of pechay was gathered by selecting excellent quality undamaged whole plants of pechay wherein the percentage marketable yield was computed out of these values (Table 3). There was significant difference (p=.0004) among treatments based on ANOVA. The highest marketable yield was obtained in the plants treated with 1rr Enersol® and inorganic fertilizer combination while the lowest marketable yield was derived from the control plots which conformed to the trend in the total fresh yield data. The results revealed that at harvest period (30 days after sowing), all Enersol® and inorganic fertilizer combination treated plants, either full or half dose inorganic when in combination with any rate of Enersol®, were significantly different from the control plants. Only the plants treated with Enersol® alone are comparable with the control plants and the plants treated with 1rr Enersol® and ½ inorganic fertilizer combination. Both the plants treated with Enersol® alone and the control plants were distinctively light green in color and smaller, making them non-marketable.

In terms of percentage, the highest marketable percentage was obtained from 1rr Enersol® + inorganic fertilizer, followed by inorganic fertilizer alone, 2rr Enersol® + ½ inorganic fertilizer, 1rr Enersol® + ½ inorganic fertilizer, 1rr Enersol® alone and finally the control plants.

Table 2. Total fresh yield of pechay treated with Enersol® and inorganic fertilizer combinations

Treatment		Mean Yield (tons/ha)			Mean
		1	2	3	
1	Inorganic fertilizer alone	89.0	76.4	68.4	77.93 A
2	1rr Enersol® alone	40.0	33.4	28.5	33.97 B
3	1rr Enersol® + inorganic fertilizer	91.0	95.0	66.6	84.20 A
4	1rr Enersol® + ½ inorganic fertilizer	70.0	87.8	51.4	69.73 A
5	2rr Enersol® + ½ inorganic fertilizer	84.6	72.4	66.2	74.40 A
6	Control	21.0	29.9	28.1	26.33 B

*cv 19.11816, p=0.0002, *Means with the same letter are not significantly different at α = 0.05 by Tukey's Studentized Range (HSD) Test*

Table 3. Marketable yield and percent marketable yield of pechay treated with Enersol® and inorganic fertilizer combinations

Treatment		Marketable Yield (kg/ha, %)			Mean
		1	2	3	
1	Inorganic fertilizer alone	84,550.00 (95.00)	76,400.00 (100.00)	66,587.40 (97.35)	75,845.80 A (97.35)
2	1rr Enersol® alone	37,396.00 (93.49)	24,408.70 (73.08)	24,467.30 (85.85)	28,757.32 BC (84.14)
3	1rr Enersol® + inorganic fertilizer	91,000.00 (100.00)	89,300.00 (94.00)	66,600.00 (100.00)	82,300.00 A (98.00)
4	1rr Enersol® + ½ inorganic fertilizer	59,521.00 (85.03)	87,800.00 (100.00)	42,831.60 (83.33)	63,384.21 AB (89.45)
5	2rr Enersol® + ½ inorganic fertilizer	81,782.80 (96.67)	59,563.50 (82.27)	61,109.20 (92.31)	67,485.17 A (90.42)
6	Control	17,850.00 (85.00)	27,131.30 (90.74)	24,447.00 (87.00)	23,142.75 C (87.58)

*cv 22.90115, p=0.0004, *Means with the same letter are not significantly different at α = 0.05 by Tukey's Studentized Range (HSD) Test.*
Note: Values in parentheses are the percentages of marketable plants per total yield

3.3 Number and Percent Non-Marketable Yield of Pechay

The percent non-marketable yield was computed by determining the non-marketable yield over the total yield and presenting in the table below (Table 4). The highest percent of non-marketable plants were obtained in the plant treated with 1rr Enersol® alone while the lowest non-marketable plants were obtained in the plants treated with 1rr Enersol® and inorganic fertilizer combination. The ANOVA showed resulted to no significant difference among the treatments. Based on the variability test, the comparability of the treatments was due to the variability among replications which does not consistently provide low or high numbers of non-marketable plants.

The deformities, damaged and unacceptable pechay plants were due to insect damage and non-application of fertilizer specifically in the control and Enersol® alone treated plants. During the trial, the application of insecticides was limited to only three times – during seed sowing and two during the vegetative stage. Thus, no insecticide application was done 10 days prior to harvesting which made them vulnerable to insect attack, particularly by aphids and insect larvae. Despite the infestation, control measures were not applied since the crop was near harvesting stage.

3.4 Plant Height of Pechay

The plant height was gathered (Table 5) during harvesting by measuring the length between the base of the plant and the tallest leaf. Significant difference *($p<.0001$)* among treatments was revealed by ANOVA. The data revealed, by mean comparison, that the tallest plants were obtained from the plants treated with 1rr

Enersol® and inorganic fertilizer combination but were not significantly different from the rest of the treatments except with the plants treated with 1rr Enersol® alone and the control. On the other hand, the shortest plants were obtained from the control but were not significantly different from the plants treated with 1rr Enersol® alone but significantly different from the plants treated with inorganic fertilizer alone or in combination with Enersol® at any rate.

3.5 Leaf Length of Pechay

The leaf width was measured from the biggest leaf of each plant sample (Table 6). The data were remarkably similar to the plant height data in terms of the relationship of treatments among each other. The Analysis of Variance (ANOVA) resulted to significant differences ($p<0.0001$) among treatments. Mean comparison test revealed that the widest leaves were obtained from the plants treated with 1rr Enersol® and inorganic fertilizer combinations but were not significantly different from the rest of the treatments except with the plants treated with 1rr Enersol® alone and the control. On the other hand, the narrowest leaves were obtained from the plants treated with 1rr Enersol® alone but were not significantly different with the control but significantly different with inorganic fertilizer alone or in combination with Enersol® at any rate.

3.6 Leaf Width of Pechay

The leaf width was gathered from the biggest leaf of each plant sample (Table 7). The ANOVA resulted to significant differences *($p<0.0001$)* among treatments. The data were remarkably similar to the plant height data in terms of the relationship of treatments among each other. Mean comparison revealed that the widest leaves were obtained from the plants treated with 1rr Enersol® and inorganic fertilizer combination but were not significantly different with the rest of the treatments except the plants treated with 1rr Enersol® and control plants. On the other hand, the narrowest leaves were obtained from the plants treated with Enersol® alone, but were not significantly different from the control plants, and was significantly different from inorganic fertilizer alone or in combination with Enersol® at any rate.

3.7 Number of Leaves of Pechay

The number of leaves data were gathered by counting all matured leaves bigger than one inch in size and summarized in Table 8. By ANOVA, there was no significant difference ($p=0.4026$) found among all the treatments evaluated, although the greatest number of leaves was obtained from the plants treated with inorganic fertilizer alone, while the least number was obtained from the control plants.

Table 4. Non-marketable yield and percent non-marketable yield of pechay treated with Enersol® and inorganic fertilizer combinations

Treatment		Non-Marketable Yield (kg/ha, %)			Mean*
		1	2	3	
1	Inorganic fertilizer alone	4,450.00 (5.00)	0.00 (0.00)	1,812.60 (2.65)	2,087.53 (2.55)
2	1rr Enersol® alone	2,604.00 (6.51)	8,991.28 (26.92)	4,032.75 (14.15)	5,209.34 (15.86)
3	1rr Enersol® + inorganic fertilizer	0.00 (0.00)	5,700.00 (6.00)	0.00 (0.00)	1,900.00 (2.00)
4	1rr Enersol® + ½ inorganic fertilizer	10,479.00 (14.97)	0.00 (0.00)	8,568.38 (16.67)	6,349.13 (10.55)
5	2rr Enersol® + ½ inorganic fertilizer	2,817.18 (3.33)	12,836.52 (17.73)	5,090.78 (7.69)	6,914.83 (9.58)
6	Control	3,150.00 (15.00)	2,768.74 (9.26)	3,653.00 (13.00)	3,190.58 (12.42)

**Not significant*

Note: Values in parentheses are the percentages of marketable plants per total yield

Table 5. Plant height of pechay treated with Enersol® and inorganic fertilizer combinations

Treatment		Plant Height (cm)			Mean
		1	2	3	
1	Inorganic fertilizer alone	27.10	24.30	26.70	26.03 A
2	1rr Enersol® alone	20.40	21.20	19.80	20.47 B
3	1rr Enersol® + inorganic fertilizer	28.10	27.00	25.20	26.77 A
4	1rr Enersol® + ½ inorganic fertilizer	25.90	26.80	25.50	26.07 A
5	2rr Enersol® + ½ inorganic fertilizer	24.50	25.10	24.60	24.73 A
6	Control	19.10	20.70	22.60	20.80 B

*cv 1.94217, p<0.0001 *Means with the same letter are not significantly different at α = 0.05 by Tukey's Studentized Range (HSD) Test*

Table 6. Leaf length of pechay with Enersol® and inorganic fertilizer combinations at harvest

Treatment		Leaf Length (cm)			Mean
		1	2	3	
1	Inorganic fertilizer alone	17.60	17.20	17.30	17.37 A
2	1rr Enersol® alone	13.10	13.50	12.50	13.03 B
3	1rr Enersol® + inorganic fertilizer	18.00	17.90	16.20	17.37 A
4	1rr Enersol® + ½ inorganic fertilizer	16.30	18.00	15.60	16.63 A
5	2rr Enersol® + ½ inorganic fertilizer	16.70	17.00	15.10	16.27 A
6	Control	12.75	13.20	14.00	13.32 B

*cv 5.396682, p<0.0001, *Means with the same letter are not significantly different at α = 0.05 by Tukey's Studentized Range (HSD) Test.*

Table 7. Leaf width of pechay with Enersol® and inorganic fertilizer combinations at harvest

Treatment		Leaf Width (cm)			Mean
		1	2	3	
1	Inorganic fertilizer alone	15.70	15.30	15.60	15.53 A
2	1rr Enersol® alone	11.30	12.60	10.80	11.57 B
3	1rr Enersol® + inorganic fertilizer	16.70	16.10	15.30	16.03 A
4	1rr Enersol® + ½ inorganic fertilizer	13.70	16.00	14.50	14.73 A
5	2rr Enersol® + ½ inorganic fertilizer	14.90	14.80	15.30	15.00 A
6	Control	10.80	12.10	12.90	11.93 B

*cv 5.745721, p<0.0001, *Means with the same letter are not significantly different at α = 0.05 by Tukey's Studentized Range (HSD) Test*

Table 8. Number of leaves of pechay with Enersol® and inorganic fertilizer combinations at harvest

Treatment		Number of leaves			Mean*
		1	2	3	
1	Inorganic fertilizer alone	7.70	4.60	4.00	5.43
2	1rr Enersol® alone	6.10	3.40	3.40	4.30
3	1rr Enersol® + inorganic fertilizer	6.50	5.10	4.60	5.40
4	1rr Enersol® + ½ inorganic fertilizer	6.30	4.40	3.70	4.80
5	2rr Enersol® + ½ inorganic fertilizer	5.30	4.10	4.20	4.53
6	Control	3.20	3.50	3.40	3.37

*cv 27.29593, p=0.4026, *Not significant*

Only a constant supply of nutrients will determine proper plant growth. However, the efficiency of fertilization is influenced by many factors, such as: soil quality (agronomic category, humus and nutrient content, pH values); the course of weather during the growing season (air temperature and amount of precipitation), and the type of fertilizers used [5]. Substances contained in fertilizers improve the absorption of nutrients from the soil, increase resistance to low and high temperatures, and strengthen the plants' ability to defend themselves against pests and diseases [23]. Plants develop properly when grown in fertile and regulated pH soil [5]. The acidic nature of the soil limits the growth and development of plants by adversely affecting the soil structure and the biological activity of its microorganisms, and in conditions of low soil pH, humus loses its adhering properties, the air-water relations deteriorate, and the activity of soil organisms is reduced [24].

Enersol® Low Dust Granules (LDG), is a mineral consisting of leonardite and humic acid [25]. Both leonardite and humic products are recognized as valuable in improving crop growth. As a fertilizer additive, Leonardite is used as a soil additive to improve a crop's ability to absorb nutrients, resulting in faster growth, healthier plants, and higher yields. Commonly used as a soil amendment, humates build on organic matter to marginal soils to improve soil texture, pH stability, and moisture-holding capacity. Enersol® LDG is 63-68% humic acid and 2-4% fulvic acid that is naturally complex with multiple plant essential nutrients at an acid pH for efficient plant uptake. It also has 75-90% organic matter and traces of macro and micronutrients. The product can be applied anytime in the growing season and is excellent for blending and storage with dry granule fertilizers. Enersol® LDG improves plant health and crop yield, by itself or blended with fertilizers. It provides better nutrient uptake and better root zone soil quality. It helps plants against stress and has micronutrients such as calcium, sulfur, nitrogen, iron, magnesium, boron, manganese, zinc copper, molybdenum, and nickel. It easily breaks down in the soil, does not generate dust during handling and in the bag, does not clump urea after blending during storage, and has a high concentration of Gascoyne leonardite.

A study by Della Lucia et al. [26] have shown that plants treated with leonardite has significantly increased the abundance of a recognized endophytic bacteria with plant-growth promoting activity, the expression level of a gene coding for auxin transport proteins, and sugar yield in sugar beet, representing an understanding of the changes induced by leonardite based biostimulant in crops. On the other hand, Humic acids (HA) are organic molecules that play essential roles in improving soil properties, plant growth, and agronomic parameters, from sources that include coal, lignite, soils, and organic materials [27]. Humic acid-based products have been used in crop production in recent years to ensure sustainability of agriculture production, due to its positive effects in soil physical, chemical, and biological characteristics, including texture, structure, water holding capacity, cation exchange capacity, pH, soil carbon, enzymes, nitrogen cycling, nutrient availability, and microbial population [28,29,30,31]; it increase soil nutrients availability, especially micronutrients by chelating and co-transporting micronutrients to plants [13]; it reduces the transportation of toxic heavy metals by precipitating them, thus reducing toxic heavy metals intake by plants [14]. Humic acids also increase crop growth by increasing plant growth promoting hormones such as auxin and cytokinin, which aid in stress resistance, nutrients metabolism, and photosynthesis [32,33,34,35,29,36].

According to Bandera [37], the use of all inorganic fertilizer in pechay production either applied on the ground or foliar is highly beneficial in terms of total marketable weight or yield. The present study has demonstrated the same results. However, not all growth enhancing solutions produce the same results as in the case of Oñal et al.'s [38] findings, where applying various levels of growth enhancer solution did not significantly enhance the growth and yield of pechay. It depends on what material is in the growth enhancing solution. Environmental factors can also affect the bio-efficacy of the fertilizers applied, as evidenced by the findings of Masarirambi et al. [39] that inorganic fertilizers were less suitable in lettuce production in river sand when compared to organic fertilizers. It is also important to consider the negative impact of continuous and overusing inorganic fertilizers, to say the least, in the environment and human health [40]. According to a study by Zhang et al. [41], results indicate that environmental awareness is not necessarily related with inorganic fertilizer overuse as the reasons for farmers' inappropriate behaviors are embedded within an intricate network of economic, social-cultural and policy-influenced factors incorporating labor and time constraints, risk-averse decisions, intergenerational division, farm size, attachment to instant gratification, land attachment, peer pressure, distortion of agricultural and land use policies, which has roots in the agricultural marginalization and urban-rural dichotomy. There should be a balance in the use of either organic or inorganic fertilizers, or both.

4. CONCLUSION

The product, Enersol® when in combination with inorganic fertilizer performed well in the trial by giving yield advantages over the control and to the inorganic fertilization alone. The study revealed that the test product was able to enhance pechay production in terms of total fresh yield, marketable yield, plant height, and leaf width with an estimated increase of more than 8%, 8%, 2%, and 3%, respectively relative to inorganic fertilizer application alone. The plants treated with Enersol® have significant improvement in yield and quality of pechay. Furthermore, the bio-efficacy data on total fresh yield, marketable yield, plant height, leaf height, and width showed significant differences with the control. The plants treated with Enersol® alone and the control plants are inferior in quality in terms of size and color. Thus, Enersol® cannot be applied as a sole fertilizer but only as an amendment to inorganic fertilization to enhance pechay production.

Generally, in this experiment, pechay was very responsive to granular fertilization and in the application of Enersol®. At a very conservative amount of 50 kilograms/hectare, the combination gave a yield advantage of 6,266.67 and 57,866.67 kgs/ha over the full dose of inorganic fertilizer alone and the control, respectively. This could be translated to additional income of PhP 600,973.65 and 5,549,413.65 at PhP 95.90/kg based on the Philippines Retail Price at the National Capital Region for 15 June 2023 over the full dose of inorganic fertilizer alone and the control, respectively https://www.ceicdata.com/en/philippines/retail-price-selected-agricultural-commodities/retail-price-pechay-national-capital-region) The data also revealed that the granular inorganic fertilization dictates the growth and performance of pechay as shown by the inferior performance of the plants treated with half dose of inorganic fertilizer even when supplemented with 2rr Enersol® as compared to the plants with full dose inorganic fertilizer application.

Soil nutrients' deficiency is the prevalent in crop production. One of the distinct advantages of inorganic fertilizers they are rich equally in all three essential nutrients: nitrogen, phosphorous, and potassium. They are also fast acting as they dissolve quickly and are immediately available to plants. In cases when plants show signs of nutrient deficiency, inorganic fertilizers have a distinct advantage over organic fertilizers, which are dependent on soil microorganisms to first break down the organic matter before nutrients can be released.

Proper fertilization consists in providing plants with nutrients in the right proportions and amounts, which will enable them to obtain maximum yields of the desired consumption quality, thus protecting the environment and natural resources as well. In the experiment carried out with the use of various combinations and rates of inorganic fertilizers and Enersol LDG, the most favorable effect in terms of its feasibility in pechay production profitability, a full dose of Enersol® in combination with one-half dosage recommended rate of inorganic fertilizer is optimal and highly recommended to obtain the highest possible growth and yield performance of pechay. Further research is recommended to explore optimal dosage and application methods for maximizing pechay production using Enersol® LDG. Leonardite-based and humic based products have been used to improve soil properties and to help plants withstand biotic and abiotic stresses, and their features must be understood to help farmers make better use of these products. Lastly, it is imperative to always consider not just the short-term benefits of using inorganic fertilizers in crop production, but also their impact in the environment and human health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/104260