Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Evaluation of Eco-Enzyme Potential as an Eco-Friendly Biostimulant on the Growth and Yield of Upland Kangkong (*Ipomoea reptans* Poir.)

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Received: 18th Aug 2026 | Revised: 27th Oct 2026 | Accepted: 27th Oct 2026

Abstract— Heavy reliance on synthetic inorganic fertilizers in upland kangkong (*Ipomoea reptans* Poir.) cultivation gradually degrades soil quality, necessitating optimization strategies using organic materials such as eco-enzyme as a biostimulant. This study aimed to evaluate eco-enzyme as a complementary biostimulant to liquid inorganic fertilizer (SPGRO) on the growth and yield of upland kangkong. The research was conducted at the greenhouse of Politeknik Pertanian dan Peternakan Mapena using a Randomized Block Design (RBD) with four treatments and six replications: P1 (Eco-enzyme 15 mL/L), P2 (SPGRO 2 mL/L), P3 (Eco-enzyme 7.5 mL/L + SPGRO 1 mL/L), and P4 (Control, without fertilizer). Growth parameters, including plant height, leaf number, and SPAD index, were observed weekly, while harvest fresh weight was recorded at 30 DAP. Data were analyzed using ANOVA ($\alpha = 0.05$) and Duncan's Multiple Range Test. Results indicated that P2 consistently produced the highest plant height (19.37 cm), leaf number (10.67), SPAD index (46.80), and fresh weight (29.50 g) with notation 'a'. However, P3 yielded a SPAD index (45.25; notation 'ab') and fresh weight (25.33 g; notation 'ab') that were statistically not significantly different from P2, while significantly outperforming P1 (19.67 g) and P4 (21.83 g). Sole eco-enzyme application (P1) was constrained by limited macronutrient (N, P, K) content. These findings demonstrate that integrating eco-enzyme as a complementary biostimulant provides an environmentally friendly and sustainable approach to support a 50% reduction in inorganic fertilizer input without a statistically significant yield penalty in upland kangkong.

Keywords— **biostimulant, eco-enzyme, efficient fertilization, *Ipomoea reptans* Poir.**

INTRODUCTION

Upland kangkong (*Ipomoea reptans* Poir.) is a leafy vegetable widely cultivated in tropical and subtropical regions, including Indonesia, due to its short growth cycle and high adaptability (Mandal and Verma, 2024). Its popularity stems from its affordability and nutritional value—rich in vitamins, minerals, and calories and notably, its status as a significant source of Vitamin A (Dibyantoro, 1996; Sharmin et al., 2021). During cultivation, water supply and nutrient availability are the primary factors determining the plant's growth rate and productivity (Iswari and Astuti, 2024).

Optimizing the growth and productivity of upland kangkong relies heavily on appropriate fertilization strategies. However, heavy and continuous reliance on synthetic inorganic fertilizers poses risks of soil degradation, environmental pollution, and escalating production costs (Bertham et al., 2022; Syamsiyah et al., 2023). To address these challenges, the integration of organic materials serves not as a total replacement for synthetic inputs, but as a biological complement capable of supporting soil chemical properties and nutrient availability (Murnita & Taher, 2021; Perwira, 2024). Driven by efforts to utilize eco-friendly organic materials, recent research has increasingly focused on eco-enzymes as sustainable biostimulants (Mulyono et al., 2026; Pradana et al., 2026).

Specifically, eco-enzyme is a complex, brown-colored solution rich in organic acids, enzymes, mineral salts, and ethanol, typically produced by fermenting kitchen waste with sugar and water in a 1:3:10 ratio (Varshini and Gayathri, 2023). Although its macronutrient levels vary and often fall below the quality standards of commercial liquid fertilizers, the solution contains essential organic nutrients, including N, P, K, and organic carbon (Fadlilla et al., 2023). Rather than serving as a primary nutrient source, eco-enzyme acts as a complementary biostimulant that can assist metabolic processes and nutrient assimilation when integrated with mineral fertilizers (Ginting and Mirwandhono, 2023). Furthermore, its active compounds exhibit bioactive properties that may support plant health under specific cultivation conditions (Benny et al., 2023).

Numerous studies have demonstrated the potential of eco-enzymes in supporting horticultural crop production, such as optimizing soil nutrient availability in mustard greens (Rachman et al., 2025) and increasing biomass in yardlong beans (Fanani et al., 2024). In water spinach

https://doi.org/10.36782/apjsafe.v14i1.729

(*Ipomoea* spp.) cultivation, previous studies have explored various organic supplementation methods, ranging from hydroponic integration (Lestari & Putri, 2022) to animal manure substitution (Iswari & Astuti, 2024) and encapsulated formulations (Permadi et al., 2025). However, while prior works indicate general growth responses, distinct research gaps remain regarding how eco-enzymes specifically interact with standardized liquid inorganic fertilizers (such as SPGRO) to allow synthetic input reduction without major yield penalties. Many existing studies evaluate eco-enzymes in isolation or under differing nutrient regimes, lacking a direct treatment comparison (sole application vs. reduced-rate combinations) supported by rigorous multi-parameter growth tracking and chlorophyll status evaluation (SPAD index).

Addressing this gap, the present study differs by explicitly evaluating the capacity of eco-enzyme not merely as a standalone organic fertilizer, but as a complementary biostimulant integrated with reduced doses of liquid inorganic fertilizer (SPGRO). We hypothesize that while sole eco-enzyme application is constrained by macronutrient limitations, its combination with synthetic fertilizer can successfully optimize nutrient use efficiency specifically enabling a 50% reduction in inorganic fertilizer input while maintaining statistically comparable growth and yield performance in upland kangkong. Therefore, this study aims to evaluate the growth responses, SPAD index, and harvest fresh weight of upland kangkong under varying integrations of eco-enzyme and liquid inorganic fertilizer.

MATERIALS AND METHODS

Research Timing, Location, and Design

This study was conducted from May to June 2024 in the greenhouse of the Mapena Agricultural and Animal Husbandry Polytechnic. The greenhouse structure features a heterogeneous environment, with partial brick walls, wire mesh fencing on other sides, and adjacent teak trees influencing ambient microclimatic conditions. A Randomized Block Design (RBD) was employed, comprising four treatments: P1 (Eco-enzyme 15 mL/L), P2 (Liquid supplementary fertilizer/SPGRO 2 mL/L), P3 (Combination of eco-enzyme 7.5 mL/L + SPGRO 1 mL/L), and P4 (Control: no eco-enzyme or SPGRO). The experiment consisted of 4 treatments with 6 blocks (replications) as the blocking factor to account for potential microenvironmental gradients within the greenhouse, yielding a total of 24 experimental units (pots). To prevent pseudoreplication and accommodate both destructive and non-destructive evaluations, each experimental unit (pot cluster) was divided into 2 separate pots: 1 pot dedicated to non-destructive observations and 1 pot dedicated to destructive harvesting. With 4 treatments, 6 blocks, and 2 pots per experimental unit, a total of 48 pots were utilized. Each pot (measuring 13 cm in diameter and 10 cm in height) was filled with a growing medium consisting of a mixture of soil and burnt rice husks at a 3:1 ratio (v/v). Five seeds of Bangkok LP-1 upland kangkong were sown in each pot. For non-destructive measurements, data were collected from 3 representative plants per pot, whereas destructive measurement (fresh weight at harvest) utilized all 5 plants within the designated destructive pot, with the final fresh weight reported as total biomass per pot.

Characteristics of Eco-Enzyme and SPGRO

The eco-enzyme used in this study was produced through a 3-month anaerobic fermentation of organic kitchen waste comprising dragon fruit, rambutan, melon, citrus, and apple peels mixed with brown sugar and air conditioning (AC) condensation water in a ratio of 1:3:10 (organic waste : sugar : water). Prior to application, the crude eco-enzyme exhibited an aromatic fermented scent, a pH of 3.56, and total dissolved solids (solubility) of 1060 ppm. The application solution was prepared by diluting 15 mL of eco-enzyme with 1 liter of water, which reduced the solution's solubility down to 191 ppm. Meanwhile, the inorganic liquid supplementary fertilizer (SPGRO) utilized contained 6% N, 2% P, 3% K, alongside essential micronutrients (Fe, Mn, Zn, Cu, Co, B, Mo, and Mg).

Cultural Practices, Application Procedures, and Data Collection

Fertilizer treatments were administered twice during the growing period specifically at 10 and 20 days after planting (DAP) via soil drenching using a uniform volume of 250 mL of solution per pot. Regular watering and irrigation were maintained uniformly across all units via direct manual watering to ensure adequate soil moisture without inducing waterlogging. Vegetative growth parameters including plant height, number of leaves, and leaf greenness index (SPAD) were recorded weekly at 7, 14, 21, and 28 DAP to observe growth dynamics over time. SPAD values were measured using a portable SPAD meter, selecting fully expanded leaves with sufficient length and width to ensure the leaf blade completely covered the optical sensor. Fresh biomass was determined destructively at harvest (30 DAP).

Statistical Analysis

All collected temporal growth and yield data were subjected to Analysis of Variance (ANOVA) using SPSS software to test the main effects of treatments according to the Randomized Block Design model, incorporating block effects. Prior to ANOVA, data were checked for normality and homogeneity of variances to verify statistical assumptions. Significant treatment effects ($p < 0.05$) were further analyzed using Duncan's Multiple Range Test (DMRT) at a 5% significance level to determine significant differences among treatment means.

RESULTS AND DISCUSSIONS

Weekly Vegetative Growth Dynamics and SPAD

Regular weekly observations conducted from week 1 to week 4 (7 to 28 Days After Planting / DAP) revealed variations in the growth dynamics of plant height, leaf number, and SPAD index across the treatments.

In the first week (7 DAP), mean plant height across all treatments was relatively uniform, ranging from 5.4 cm to 6.1 cm. Distinct differences began to emerge by weeks 3 and 4. At week 4, the full inorganic fertilizer treatment P2 (SPGRO) recorded the highest plant height at 19.4 cm, followed by the combination treatment P3 (16.9 cm), the

https://doi.org/10.36782/apjsafe.v14i1.729

control P4 (15.6 cm), and the sole eco-enzyme treatment P1, which yielded the lowest growth (14.3 cm). This indicates that macro-nutrient availability (N, P, K) from inorganic fertilizers plays a decisive role in regulating stem elongation rates during the active vegetative phase.

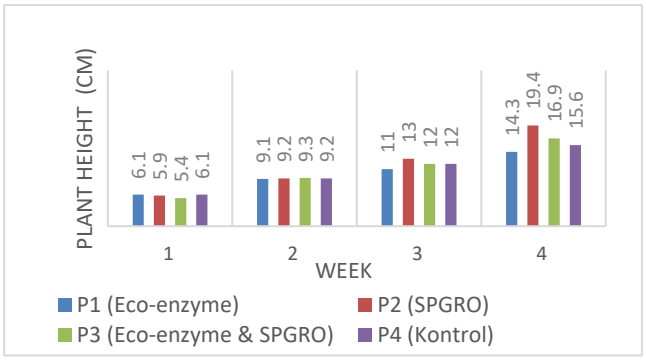


Figure 1. Observations of plant height over 1 month

Leaf formation exhibited a linear growth pattern as plants matured. At week 1, all treatments produced an average of 2 leaves. By week 2, leaf count increased uniformly to 5 leaves across all treatments. Differentiation became noticeable at week 3 (P2 reached 8 leaves, while P1, P3, and P4 maintained 7 leaves) and became more pronounced at week 4. At the final observation (week 4), treatment P2 produced the highest number of leaves (11 leaves), followed by the combination treatment P3 (10 leaves), and P1 and P4 with 9 leaves each.

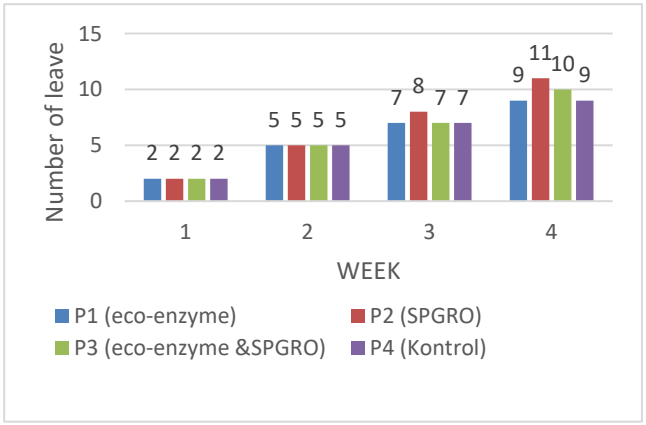


Figure 2. Observation of the number of leaves over 1 month

Based on non-destructive measurements using a portable SPAD meter, leaf greenness values demonstrated a consistent trend in which treatments involving inorganic nutrient supply (P2 and P3) maintained higher SPAD indices compared to the sole eco-enzyme treatment (P1) and control (P4) from week 1 through week 4. SPAD values in P1 and P4 even exhibited a declining trend toward the end of the vegetative phase (dropping to 28.9 and 42.9 at week 4, respectively), indicating limited nutrient availability—particularly Nitrogen and Magnesium, which are vital for chlorophyll synthesis—in growing media lacking adequate inorganic fertilizer supplementation.

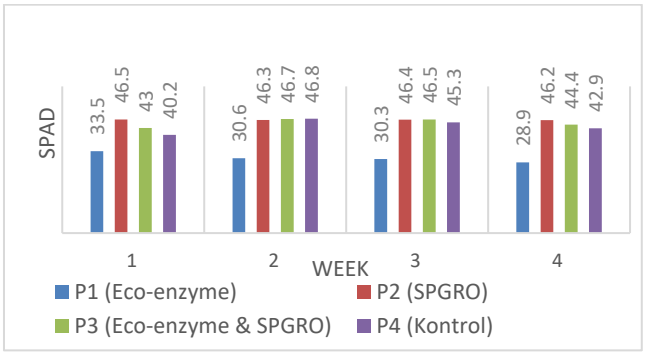


Figure 3. SPAD observations for 1 month

Overall, these temporal weekly data confirm that while sole eco-enzyme application (P1) failed to optimally drive vegetative growth due to inherent macro-nutrient limitations, combining half-dose eco-enzyme with half-dose inorganic fertilizer (P3) successfully maintained stable leaf growth dynamics and leaf greenness closely approaching the performance of full inorganic fertilization (P2).

Final Growth Evaluation and SPAD Index

Based on Duncan's Multiple Range Test at the 5% significance level (Table 1), the full inorganic fertilizer treatment P2 (SPGRO 2 mL/L) recorded the highest values across all final vegetative growth parameters and the SPAD index, including plant height (19.37 cm), number of leaves (10.67), and leaf greenness/chlorophyll index (46.80 SPAD units), all denoted by 'a' and showing statistically significant differences compared to other treatments. The enhanced growth and accumulation of leaf greenness pigments observed in P2 were driven by the direct supply of readily absorbable macronutrients (N, P, K) and micronutrients from the full synthetic inorganic fertilizer, which optimally supported the active vegetative growth phase of the plants (Kurniawan et al., 2025). These macronutrients played a direct role in stimulating vegetative organ formation, such as root elongation and cell division, which accelerated plant height growth (Fadila et al., 2021). Specifically, Nitrogen (N) and Magnesium (Mg) served key roles as primary structural components of chlorophyll molecules, which are essential for optimizing the rate of photosynthesis to generate photosynthates that build plant tissues and new leaves (Suroso & Antoni, 2016; Fevria et al., 2023).

Meanwhile, the combination treatment P3 (Eco-enzyme 7.5 mL/L + SPGRO 1 mL/L) ranked second in plant height (16.88 cm, notation 'b') and number of leaves (9.50, notation 'b'), while yielding a SPAD index of 45.25 units (notation 'ab'). The SPAD value in P3 did not differ statistically from treatment P2 ('a'). However, it is important to carefully note that the 'ab' notation in P3 also shares the letter 'b' with the control treatment P4 (42.87 SPAD units, notation 'bc'). Consequently, rather than outright surpassing the control on the SPAD parameter, P3 represents an intermediate response range that is statistically comparable to both P2 and P4. Nevertheless, these findings confirm that reducing the inorganic fertilizer dosage by up to 50% when combined with eco-enzyme successfully maintains effective leaf greenness levels and vegetative growth rates close to full inorganic fertilization (Lestari & Putri, 2022).

https://doi.org/10.36782/apjsafe.v14i1.729

Table 1. Effect of treatments on plant height, number of leaves, and SPAD at week 4

Treatment	Observation Variables		
	Plant Height (cm)	Number of leaves	SPAD Unit
P1	14,27 c	8,67 c	40,20 c
P2	19,37 a	10,67 a	46,80 a
P3	16,88 b	9,50 b	45,25 ab
P4	15,57 bc	8,83 bc	42,87 bc
CV (%)	11,74	6,28	5,54

Description: Mean values followed by different letters in the same column indicate significant differences based on Duncan's test at the 5% level. CV = Coefficient of Variation.

Conversely, the sole eco-enzyme application treatment P1 (15 mL/L) exhibited the lowest averages in plant height (14.27 cm, notation 'c'), number of leaves (8.67, notation 'c'), and SPAD index (40.20 SPAD units, notation 'c'), where its height and leaf count showed no statistically significant difference from the control P4 ('bc'). The limited growth observed in P1 is attributable to the restricted macronutrient content within crude eco-enzyme. According to the Decree of the Minister of Agriculture of the Republic of Indonesia No. 261 of 2019 regarding Organic Fertilizer Quality Standards, macronutrient levels (N, P, K) in pure eco-enzymes generally fall below the qualification standards for commercial liquid organic fertilizers; specifically, the average total NPK content is less than 2% and organic carbon is less than 10%. Such restricted nutrient concentrations are insufficient to meet the demands of upland kangkong during its rapid vegetative growth phase, as NPK availability in eco-enzymes heavily relies on subsequent decomposition and mineralization processes of the growing medium's organic matter (Fadlilla et al., 2023).

Theoretically, eco-enzymes are not primarily functioned as major nutrient-supplying fertilizers; rather, literature frequently proposes them as having potential biostimulatory roles containing organic acids and active enzymes that support the rhizosphere environment (Benny et al., 2023; Ginting and Mirwandhono, 2023). However, because specific biological parameters such as soil enzyme activity or direct nutrient solubilization were not directly measured in this study, the sole application of eco-enzyme (P1)—lacking supplemental inorganic Nitrogen and Magnesium—proved insufficient to support maximum chlorophyll synthesis and vegetative growth in upland kangkong. This finding further reinforces the position of eco-enzymes as complementary biostimulants rather than complete substitutes for synthetic fertilizers (Perwira, 2024).

Fresh weight

Based on Duncan's test at the 5% level (Table 2), the fertilization treatments significantly affected the fresh weight of upland kangkong at harvest. Treatment P2 (SPGRO 2 mL/L) recorded the highest average fresh weight at 29.50 grams (notation 'a'). This value did not differ significantly from the combination treatment P3 (Eco-enzyme 7.5 mL/L + SPGRO 1 mL/L), which yielded 25.33 grams (notation 'ab'). However, treatment P2 resulted in a significantly higher fresh weight compared to P1 (Eco-enzyme 15 mL/L) at 19.67 grams (notation 'b') and the control P4 at 21.83 grams (notation 'b').

Although the statistical analysis shows that P3 ('ab') is not significantly different from P2 ('a'), it is important to acknowledge objectively that the mean fresh weight of P3 was approximately 14.1% lower than that of P2. Consequently, while the combination treatment allows for a 50% reduction in inorganic fertilizer input without a statistically significant yield penalty, this should not be interpreted as achieving completely identical or uncompromised yield performance.

Table 2. Application of treatments on plant weight.

Treatment	Harvest Observation Variables
	Plant Fresh Weight (grams)
P1	19,67 b
P2	29,50 a
P3	25,33 ab
P4	21,83 b
CV	18,91

Description: Mean values followed by different letters in the same column indicate significant differences based on Duncan's test at the 5% level. CV = Coefficient of Variation.

The low biomass accumulation observed with the sole application of eco-enzyme (P1) is attributed to the fact that eco-enzymes lack macronutrients (N, P, K) in quantities sufficient to influence parameters heavily dependent on primary nutrient availability, such as shoot weight and stem diameter. The biostimulant effect of eco-enzymes tends to be more dominant in promoting early vegetative responses, yet it remains insufficient to significantly increase final biomass in the absence of an adequate macronutrient supply (Calvo et al., 2014). This phenomenon aligns with the inherent limitations of sole eco-enzyme application, as similarly demonstrated by Mandal and Verma (2024) in radish plants, where unsupplemented eco-enzyme treatments yielded the lowest plant weight, whereas maximum biomass was achieved under full inorganic fertilization.

CONCLUSIONS

Based on the research results, the full inorganic fertilizer treatment P2 (SPGRO 2 mL/L) consistently yielded the best growth responses in terms of plant height (19.37 cm), number of leaves (10.67), SPAD index (46.80), and harvest fresh weight (29.50 g) with notation 'a'. However, the combination treatment P3 (Eco-enzyme 7.5 mL/L + SPGRO 1 mL/L) produced a SPAD index (45.25; notation 'ab') and fresh weight (25.33 g; notation 'ab') that were not statistically significantly different from P2, while significantly outperforming the sole eco-enzyme treatment (P1), which showed the poorest growth due to key macronutrient limitations. Overall, these findings indicate that eco-enzyme functions as a promising complementary biostimulant that supports a 50% reduction in inorganic fertilizer input while maintaining acceptable vegetative growth and yield performance in upland kangkong.

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