International Journal of Natural Science Studies and Development (IJOSS)
Volume 3 Issue 1 2025 pp 289-307
E-ISSN: 2615-1383
DOI: https://doi.org/10.55299/ijoss.v3i1.39

The Effect of Moringa Leaf Liquid Organic Fertilizer and Trichoderma on Growth and Yield of Lettuce (Lactuca sativa L.)

Narudi[1], Rasmita Adelina[2*)], Dini Puspita Yanty[3], Sutan Pulungan[4]

[1,2,3,4]*Graha Nusantara University, Padangsidimpuan, Indonesia*
**Corresponding author: rasmita301271@gmail.com*

Abstract

Lettuce (Lactuca sativa L.) is a vegetable with numerous benefits and high economic value. The objective of this study was to determine the effect of moringa leaf liquid organic fertilizer (POC) and Trichoderma on lettuce growth and production. The study was conducted in Neighborhood VI, Pasar Sibuhuan Village, Barumun District, Padang Lawas Regency, North Sumatra, in March 2025. The research method is an experimental study, using a factorial randomized block design. The first factor is liquid organic fertilizer of moringa leaves with 3 levels, namely P0 = Without giving liquid organic fertilizer of moringa leaves, P1 = liquid organic fertilizer of moringa leaves (120 ml/L), P2 = liquid organic fertilizer of moringa leaves (220 ml/L). The second factor is Trichoderma with 3 levels, namely T0 = Without Trichoderma, T1 = Trichoderma (20 gr/polybag), P2 = Trichoderma (30 gr/polybag). The parameters observed are plant height (cm), number of leaves (strands), leaf length (cm), leaf width (cm) and fresh weight (grams). The results of the study showed that the administration of liquid organic fertilizer from Moringa leaves significantly affected the initial vegetative growth (height, leaf length) and production of lettuce plants (P1 dose of 120 ml/L), while the Trichoderma treatment also significantly affected the growth and production of lettuce plants. The dose of 30 g/polybag (T2) had a positive effect, especially in increasing the number and width of leaves, as well as supporting the formation of plant biomass. The combination of moringa leaf POC and Trichoderma yielded the best results for lettuce growth and yield. The P1T2 treatment combination (120 ml/L and 30 g/polybag) was shown to produce the highest plant height and fresh weight.

Keywords: *lettuce, moringa leaf POC, Trichoderma lettuce, moringa leaf POC, Trichoderma*

1. INTRODUCTION

Lettuce (Lactuca sativa L.) is one of the most commercially important leafy vegetables globally and is valued for its nutritional content, versatility in culinary applications, and economic significance in horticultural production systems. This annual crop, belonging to the family Asteraceae, contains substantial water content (94-95%), is low in calories, and provides essential vitamins, including vitamin C, vitamin A, and vitamin B complex, along with minerals, such as calcium and iron. Per 100 grams of fresh weight, lettuce contains approximately 1.2 g protein, 0.2 g fat, 22.0 mg calcium, 162 mg vitamin A, and 8.0 mg vitamin C, making it an important component of healthy diets worldwide (Medina LI, Bertolín JR., 2021).

History:
Received : December 13, 2025
Revised : January 15, 2025
Accepted : February 10, 2026
Published : February 17, 2026

Publisher: Inovasi Pratama Int. Press

The economic importance of lettuce cultivation in Indonesia has increased substantially in recent decades, driven by the growing consumer awareness of nutritional requirements and expanding urban populations. In North Sumatra Province, lettuce production data from 2021 to 2023 show fluctuating yields of 74,908 tons, 74,370 tons, and 77,970 tons, respectively, whereas Padang Lawas Regency specifically produced 3,330 tons, 3,200 tons, and 3,392 tons, respectively during the same period. These fluctuations indicate production instability and suggest a significant potential for yield optimization through improved cultivation practices. Indonesian vegetable consumption patterns reveal that while 97.29% of the population consumes vegetables, the average intake remains only 173 g per capita per day, substantially below the Food and Agriculture Organization (FAO) recommended standard of 400 g per capita per day (Badan Pusat Statistik, 2022).

Traditional lettuce cultivation in Indonesia relies heavily on synthetic chemical fertilizers and pesticides, which have generated increasing environmental and public health concerns. Prolonged application of inorganic fertilizers causes soil degradation, reduces organic matter content, increases soil compaction, diminishes microbial diversity, and compromises soil fertility and structure. These detrimental effects necessitate the exploration of sustainable alternative approaches that maintain or enhance productivity while minimizing the environmental impact. Organic agriculture, particularly through application of liquid organic fertilizers and beneficial microorganisms, offers promising solutions to address these challenges (Paulina, M., Lumbantoruan, S. M., & Septiani, 2020).

Moringa (Moringa oleifera Lam.), commonly known as the drumstick tree or horseradish tree, has emerged as an exceptional candidate for organic fertilizer production because of its remarkable nutritional and biochemical composition. Moringa leaves contain extraordinarily high levels of essential nutrients, including 28.44% protein, 57.01% carbohydrates, 2.74% fat, and 7.95% ash on a dry weight basis. Moringa leaves contain macronutrients essential for plant growth, including nitrogen (4.02%), phosphorus (1.17%), potassium (1.80%), calcium (12.3%), magnesium (0.10%), and sodium (1.17%). Beyond basic nutrients, moringa leaves are rich in bioactive phytochemicals, including zeatin, phenolic compounds, ascorbate, and various mineral salts, such as calcium, potassium, and iron, which function as natural plant growth promoters (Yani et al., 2022).

The presence of cytokinins, particularly zeatin, in the moringa leaf extract distinguishes it from conventional organic fertilizers. Zeatin concentrations in moringa leaves are remarkably high compared with those in other plant materials, reaching levels that significantly influence plant physiological processes. Cytokinins play crucial roles in plant development by stimulating cell division, promoting lateral shoot formation, delaying senescence, enhancing nutrient mobilization, and improving stress tolerance. When applied as a foliar spray or soil drench, moringa-derived cytokinins are rapidly absorbed and translocated throughout plant tissues, triggering developmental responses that enhance vegetative growth and productivity. Research has demonstrated that Moringa leaf extract significantly improves various growth parameters, including plant height, leaf number, leaf area, and biomass accumulation in multiple horticultural crops. The hormonal effects of moringa extract complement its nutritional contributions, creating synergistic effects that enhance overall plant performance beyond what would be expected from the nutrient supply alone (Saragih Evi Warintan et al., 2021).

Liquid organic fertilizers derived from moringa leaves offer several advantages over solid organic fertilizer. The liquid formulation facilitates rapid nutrient availability as constituent elements exist in dissolved or colloidal forms that are immediately accessible for plant uptake. Application methods are simpler and more uniform, allowing precise dosing through irrigation systems or foliar sprays. The fermentation process used in liquid fertilizer production also enriches the product with beneficial microorganisms that contribute to the biological activity of soil. Furthermore, liquid fertilizers can be applied at intervals matching crop growth stages, providing nutrients when plants have the maximum capacity to utilize them efficiently. Previous research on various crops has confirmed the efficacy of moringa-based liquid organic fertilizers. Studies on green onions reported optimal growth at a concentration of 120 ml/L, while cucumber and tomato trials demonstrated significant improvements in vegetative parameters and fruit quality with moringa extract application (Adelina, R., Harahap, S., Amnah, R. Nasution, 2023).

Complementing the nutritional benefits of organic fertilizers, beneficial soil microorganisms play increasingly recognized roles in sustainable agriculture. Among these, species of the fungal genus Trichoderma have received particular attention owing to their versatile beneficial effects on plant growth, soil health, and disease suppression. Trichoderma spp. are free-living soil fungi that are ubiquitous in agricultural soils and are characterized by rapid growth rates, prolific spore production, and the ability to utilize diverse organic substrates. Multiple mechanisms contribute to the plant growth-promoting effects of Trichoderma spp. First, these fungi produce various extracellular enzymes, including cellulases, hemicellulases, chitinases, and proteases, which accelerate the decomposition of organic matter and release nutrients in plant-available form. This enhanced mineralization increases the nutrient cycling efficiency and improves soil fertility. Second, Trichoderma spp. synthesize phytohormones, including auxins, gibberellins, and cytokinins, which directly stimulate plant growth processes. Third, Trichoderma colonization of root systems induces changes in root architecture, typically increasing root length, surface area, and branching density, which expand the volume of soil from which plants can extract water and nutrients (Tomia & Pelia, 2021).

Beyond promoting growth, Trichoderma spp. provide biological control against soil-borne pathogens through multiple antagonistic mechanisms. These include competition for nutrients and colonization sites, production of antibiotic metabolites, mycoparasitism through direct hyphal interactions, enzymatic degradation of pathogen structures, and induction of systemic resistance in host plants. The biocontrol capabilities of Trichoderma offer environmentally benign alternatives to synthetic fungicides, addressing concerns about pesticide residues, environmental contamination, and the development of pathogen resistance. Field studies across diverse cropping systems have documented significant disease reduction and yield improvement following Trichoderma application. Importantly, Trichoderma effects extend beyond pathogen suppression and include enhanced stress tolerance, improved nutrient acquisition, and stimulation of plant defense mechanisms, collectively contributing to improved crop performance (Suhastyo & Raditya, 2021).

Synergistic interactions between organic fertilizers and beneficial microorganisms such as Trichoderma have emerged as a promising approach for sustainable agriculture. Organic amendments provide carbon and energy sources that support Trichoderma proliferation and activity in soil. Concurrently, Trichoderma enzymes accelerate organic matter decomposition, making nutrients from organic fertilizers available to plants more rapidly. This mutualistic relationship creates positive feedback loops that enhance both the soil biological activity and nutrient cycling efficiency. Research integrating organic fertilizers with Trichoderma has demonstrated additive or synergistic effects that exceed those of either application alone. For instance, studies on rice reported that biochar enriched with Trichoderma combined with organic amendments effectively reduced soil acidity, decreased bulk density, increased root volume, and significantly improved grain yield compared to individual treatments (Sari, S. W., Safruddin, & Purba, 2019).

The rhizosphere, a narrow soil zone directly influenced by plant roots, represents the primary arena where these interactions occur. Trichoderma preferentially colonizes the rhizosphere because of the abundance of root exudates that serve as nutrient sources. Once established, Trichoderma modifies rhizosphere characteristics by altering the pH, increasing enzyme activities, and shifting the microbial community composition. These modifications generally favor beneficial microorganisms, including plant growth-promoting rhizobacteria (PGPR), nitrogen-fixing bacteria, and phosphate-solubilizing microorganisms. PGPR are diverse bacterial groups inhabiting the rhizosphere that benefit plant growth through various mechanisms, including nitrogen fixation, phosphate solubilization, siderophore production for iron acquisition, synthesis of phytohormones, degradation of plant ethylene precursors to reduce stress, and biocontrol activity against pathogens. The synergy between Trichoderma and PGPR creates a beneficial microbial consortium that maximizes plant growth promotion and disease suppression (Mare.T.W., Gresinta E., 2022).

Despite growing recognition of the benefits of organic fertilizers and biological agents individually, limited research has systematically evaluated their interactive effects on lettuce production, particularly under tropical Indonesian conditions. Most previous studies have examined these inputs in isolation, leaving questions about optimal combinations, application rates, timing, and mechanisms underlying synergistic interactions. Furthermore, lettuce, as a fast-growing leafy vegetable with relatively short production cycles, may respond differently to organic inputs than crops with longer growth periods. The shallow root system of lettuce may particularly benefit from the enhanced nutrient availability and root development promoted by Trichoderma. Additionally, the environmental conditions in tropical Indonesia, including high temperatures, intense rainfall, and diverse pest and disease pressures, create specific challenges and opportunities for organic production systems that warrant investigation (Widyarti, N. M. P., dan Tambing, 2023).

This study addresses these knowledge gaps by systematically evaluating the effects of moringa leaf liquid organic fertilizer and Trichoderma on lettuce growth and productivity, both individually and in combination. This study tested multiple application rates of each input to identify the optimal dosages for lettuce production. Comprehensive measurements of vegetative growth parameters throughout the growing season, combined with yield assessment at harvest, provided a detailed characterization of treatment effects. The research was conducted in the typical lowland conditions of North Sumatra, enhancing the practical relevance for regional farmers. The results of this study contribute to the scientific knowledge base supporting sustainable vegetable production systems, while providing practical guidance for farmers seeking to reduce synthetic input dependency, improve soil health, and enhance product quality through organic cultivation practices.

The specific objectives of this syudy were to: (1) determine the effects of moringa leaf liquid organic fertilizer at different concentrations on lettuce growth and yield parameters; (2) evaluate the effects of Trichoderma application at different rates on lettuce development and productivity; and (3) assess the interactive effects of moringa leaf POC and Trichoderma treatments to identify optimal combinations for lettuce production. We hypothesized that (1) moringa leaf POC application would significantly enhance lettuce vegetative growth and yield through combined nutritional and hormonal effects, (2) Trichoderma inoculation would improve lettuce performance by enhancing nutrient availability and root development, and (3) combined application of moringa leaf POC and Trichoderma would produce synergistic effects exceeding those of individual treatments, resulting in superior growth and productivity. Understanding these relationships will facilitate the development of integrated organic nutrient management strategies optimized for lettuce, and may be applicable to other intensive vegetable cropping systems.

2. METHOD

This study was conducted from March to April 2025 in Neighborhood VI, Pasar Sibuhuan Village, Barumun District, Padang Lawas Regency, North Sumatra Province, Indonesia. The experimental site was located approximately 154 m above sea level, with tropical lowland climate characteristics. Average daytime temperatures during the experimental period ranged from to 28-32°C with nighttime temperatures of 22-25°C. Rainfall occurred intermittently, but was supplemented with controlled irrigation to maintain consistent soil moisture appropriate for lettuce cultivation (Creswell, 2021).

The plant material consisted of lettuce (Lactuca sativa L.) variety Green Lactuca (curly green type), selected for its adaptation to lowland tropical conditions, market preference in the region, and consistent performance in previous trials. The seeds were obtained from a certified agricultural supply store to ensure genetic purity and germination quality. Growth medium components included topsoil collected from agricultural fields, commercially available rice hull biochar (sekam bakar), and well-composted cattle manure. These components were mixed at a 3:2:1 ratio (soil:manure:biochar) to create a growth medium with balanced physical properties, adequate nutrient content, and good drainage characteristics. The pH of the media was adjusted to the optimal range for lettuce (5.5-6.0) through application of agricultural lime (dolomite) as needed.

Moringa leaf liquid organic fertilizer (POC) was prepared using standardized fermentation procedures. Five kilograms of Fresh moringa leaves were harvested from mature trees, thoroughly washed to remove dust and contaminants, and macerated using a commercial blender until they were homogenous. The macerated material was mixed with five liters of fresh coconut water (providing natural sugars and minerals that enhance fermentation), 100 g of dissolved brown sugar (supplying readily fermentable carbohydrates), and 500 ml of an effective microorganism solution (EM4, a commercial microbial consortium). The mixture was placed in sealed containers and periodically stirred twice daily (morning and evening) to ensure uniform fermentation. Fermentation proceeded for 21 days at ambient temperature until the product exhibited a characteristic brown coloration and mild fruity aroma, indicating successful fermentation. The completed fertilizer was filtered through a cloth to remove particulate matter, yielding a liquid fertilizer suitable for application. Laboratory analysis of the finished POC revealed a nitrogen content of 0.12%, phosphorus (as P_2O) concent of 0.10%, and potassium (as K_2O) content of 1.51%.

The Trichoderma inoculum was obtained from a commercial source specializing in biological agricultural products. The product contained Trichoderma spores at a minimum concentration of 10 colony-forming units per gram mixed with inert carrier material, facilitating application and storage. Quality verification included microscopic examination to confirm the presence of typical Trichoderma conidial structures and viability testing on culture media demonstrating active growth and sporulation.

The experiment employed a factorial randomized complete block design (RCBD) with two factors and three replications. The first factor was moringa leaf liquid organic fertilizer (POC) at three levels: P_0 = control without POC application; P_1 = POC at 120 ml/L water; P_2 = POC at 220 ml/L water. The second factor was Trichoderma at three levels: T_0 = control without Trichoderma; T_1 = Trichoderma at 20 g per polybag; and T_2 = Trichoderma at 30 g per polybag. The factorial arrangement generated nine treatment combinations (P_0T_0, P_0T_1, P_0T_2, P_1T_0, P_1T_1, P_1T_2, P_2T_0, P_2T_1, P_2T_2), each replicated three times for a total of 27 experimental units. Each experimental unit consisted of a single polybag containing one lettuce plant with two plants per unit designated for data collection. The total plant population comprised 81 plants, with 54 sampling plants. The spatial arrangement included 20 cm spacing between plots, 10 cm between individual polybags within plots, and 30 cm between replicate blocks.

Data were analyzed statistically using Analysis of Variance (ANOVA) with the linear model: Y_{ijk} = μ + A_i + K_j + (AK)_{ij} + ε_{ijk}, where Y_{ijk} represents the observed value for POC level i, Trichoderma level j, and replication k; μ is the overall mean; A_i is the effect of Trichoderma level j; K_{ij} is the interaction effect between POC level I and Trichoderma level j; (ε _{ijk} is the interaction effect between POC level i and Trichoderma level j; and ε_{ijk} is the random error term. When ANOVA indicated significant treatment effects ($P < 0.05$), means were separated using the Least Significant Difference (LSD) test at a 5% probability level. All statistical analyses were performed using the SPSS version 25 software.

Site Preparation and Media Preparation: The experimental area was cleared of existing vegetation, debris removed, and surface leveled to facilitate a uniform polybag arrangement. Polybags (30 cm diameter × 30 cm height) were filled with prepared growth media (soil:manure:biochar at a 3:2:1 ratio) to approximately 2 cm below the rim to prevent overflow during irrigation. The media components were thoroughly mixed before filling to ensure homogeneity across all experimental units.

Seed Sowing and Seedling Production: Lettuce seeds were sown in small nursery polybags containing a finely textured media mixture of soil and composted manure (1:1 ratio). Two to three seeds were placed per container at 0.5 cm depth, covered lightly with fine soil, and irrigated gently. The nursery containers were maintained under partial shade with twice-daily irrigation to maintain consistent moisture. Seedlings were grown for two weeks until the transplanting stage characterized by 3-4 true leaves and vigorous root development.

Trichoderma Application: Trichoderma inoculum was incorporated into the growth media two weeks before transplanting to allow colonization and establishment. The specified amount of Trichoderma (20 or 30 g per polybag depending on the treatment) was mixed thoroughly into the upper layer of the media in each polybag receiving Trichoderma treatments. The control polybags did not receive any Trichoderma addition. This pre-planting application strategy facilitated the establishment of Trichoderma in the rhizosphere zone before roots became extensive.

Transplanting: Two-week-old seedlings were transplanted into experimental polybags in the late afternoon to minimize the transplant shock from high temperature and solar radiation. Seedlings of uniform size and health status were selected to ensure straight stems, fresh green foliage, and the absence of pest or disease symptoms. Transplanting was performad carefully to minimize root disturbance. One seedling was established per polybag, inserted at the same depth as in the nursery container, and the medium was gently firmed around the roots. Immediate post-transplant irrigation ensured good root-media contact and prevented desiccation stress.

POC Application: Liquid organic fertilizer applications commenced seven days after transplanting (7 DAT) once plants had recovered from transplant stress and initiated new growth. POC was diluted to the specified concentrations (120 or 220 ml/L water) immediately before application. Applications were made every three days throughout the growth period by pouring the diluted fertilizer solution around the base of each plant, directing the liquid toward the root zone. The application volume was standardized to ensure uniform treatment delivery. Control plants received equivalent volumes of water without the addition of POC.

Cultural Management: Standard cultural practices were implemented uniformly across all experimental units. Irrigation was applied twice daily (morning and evening) using watering cans to maintain soil moisture near field capacity, without waterlogging. Plants that died within seven days of transplanting were replaced with reserve seedlings of equivalent age to maintain stand uniformity. Weeding was performed manually as needed, typically once every two weeks, removing weeds from both within polybags and in spaces between experimental units. Pest management was conducted mechanically when necessary, The primary pest encountered was snails, which were hand-collected and removed. No disease symptoms were observed during the experimental period, precluding the need for disease-management interventions. Bamboo stakes (1 cm wide × 40 cm height) were inserted vertically adjacent to each plant to serve as reference points for height measurements, with the base of each stake marked at the soil level to ensure measurement consistency (Sugiyono, 2019).

Harvesting: Lettuce was harvested 42 d after transplanting when the plants reached marketable maturity. Harvest indices included lower leaves that began to touch the soil surface and the bottommost leaves, showing a slight yellowing characteristic of mature lettuce. Plants were harvested by gently pulling the entire plant, including the root system, from the polybag media, and the excess soil was shaken from the roots. The harvested plants were immediately transported to the measurement area for data collection (Arikunto, 2016).

Plant Height: Plant height was measured 14, 21, 28, and 35 days after transplanting (DAT). Measurements were made from the permanent mark on the reference stake at the soil level to the apex of the tallest leaf using a ruler graduated in millimeters. Values were recorded in centimeters to one decimal place.

Leaf Number: Total leaf count was measured at the same intervals as the height measurements (14, 21, 28, and 35 DAT). All leaves visible to the unaided eye were counted, regardless of size, including both fully expanded and developing leaves.

Leaf Length: Leaf length was measured at 14, 21, 28, and 35 DAT. The longest fully expanded leaf on each plant was identified and the length was measured from the point of petiole attachment to the leaf blade tip using a ruler. Measurements were recorded in centimeters to one decimal place.

Leaf Width: Leaf width was measured at the same time as the other vegetative parameters. The widest portion of the leaf used for length measurement was identified, and the width was measured perpendicular to the midrib at that point. Values were recorded in centimeters to one decimal place.

Fresh Weight: At harvest (42 DAT), whole plants, including roots, stems, and all leaves, were weighed immediately after removal from polybags using a digital balance with 0.1 a precision. Plants were not washed to avoid water absorption, which artificially inflated the weight measurements. Fresh weight values were recorded in grams.

Soil and Fertilizer Analysis: Representative samples of both moringa leaf POC and growth media from each treatment combination were collected and submitted to the Soil, Plant, Fertilizer, and Water Laboratory of the North Sumatra Agricultural Research and Development Center (BRMP) for chemical analysis. POC samples were analyzed for total nitrogen, available phosphorus (P_2O), and available potassium (K_2O). The soil samples were analyzed for nitrogen content, available phosphorus (Bray-1 method), and exchangeable potassium. Laboratory results provided a baseline characterization of the nutrient status for the interpretation of treatment effects.

3. **RESULTS AND DISCUSSION**

Results

Laboratory analysis of the fermented moringa leaf liquid organic fertilizer revealed the following nutrient concentrations: total nitrogen, 0.12%; available phosphorus (as P_2O), 0.10%; and available potassium (K_2O), 1.51%. These values indicate that the POC produced in this study contained modest nitrogen and phosphorus levels but a relatively high potassium content. The nitrogen concentration was lower than that reported in previous studies, possibly reflecting dilution from coconut water and sugar additions during fermentation, as well as potential nitrogen volatilization during the fermentation process. High potassium content is characteristic of moringa leaf composition and is retained through out the fermentation process. While the macronutrient levels in this POC were not exceptionally high compared to some commercial liquid fertilizers, the bioactive compounds, including phytohormones (particularly cytokinins), amino acids, vitamins, and secondary metabolites present in moringa extracts, likely contributed substantially to the observed plant growth effects beyond simple nutrient supply.

Table 1.

POC Treatment	*Trichoderma* Treatment	Combination Code	POC Concentration (ml/L)	*Trichoderma* Rate (g/polybag)
P_0 (Control)	T_0 (Control)	P_0T_0	0	0
P_0 (Control)	T_1	P_0T_1	0	20
P_0 (Control)	T_2	P_0T_2	0	30
P_1	T_0 (Control)	P_1T_0	120	0
P_1	T_1	P_1T_1	120	20
P_1	T_2	P_1T_2	120	30
P_2	T_0 (Control)	P_2T_0	220	0
P_2	T_1	P_2T_1	220	20
P_2	T_2	P_2T_2	220	30

Soil analysis results for the growth media under different treatments showed variation in nutrient levels. Nitrogen content ranged from 0.25% (P_0T_0) to 0.37% (P_2T_1), with most treatments falling between 0.30-0.35%. Available phosphorus (Bray-1 method) showed considerable variation from 1.41 ppm (P_0T_1) to 14.72 ppm (P_0T_2), with most values in the range of 2-8 ppm. Exchangeable potassium ranged from 0.30 me/100g (P_0T_0) to 1.74 me/100g (P_2T_1), with treatments receiving POC or Trichoderma generally showing higher values than the control. These patterns suggest that both POC applications and Trichoderma inoculation influenced nutrient dynamics in the growth media. The highest nitrogen and potassium values in the P_2T_1 treatment (0.37% N and 1.74 me/100g K) suggest potential synergistic effects between POC and Trichoderma on nutrient availability. The variable phosphorus levels may reflect complex dynamics of phosphorus transformations influenced by microbial activity, pH changes, and organic matter interactions. Overall, the growth media provided adequate nutrient availability for lettuce growth, with treatment-induced variations providing partial explanation for observed differences in plant growth and yield.

Table 2. Chemical Composition of Moringa Leaf Liquid Organic Fertilizer (POC)

Chemical Component	Concentration	Unit
Total Nitrogen (N)	0.12	%
Available Phosphorus (P_2O_5)	0.10	%
Available Potassium (K_2O)	1.51	%
Organic Matter	8.45	%
pH	6.8	-

Analysis of variance for plant height revealed significant treatment effects at early growth stages, but diminished effects as plants matured. At 14 days after transplanting (DAT), both main effects (POC and Trichoderma) were significant, with POC significant at $P < 0.05$, and Trichoderma highly significant at $P < 0.01$. Importantly, the interaction between POC and Trichoderma was also significant ($P < 0.05$) at 14 DAT. At 21 DAT, POC effects became highly significant ($P < 0.01$), whereas Trichoderma remained significant ($P < 0.05$), but the interaction effect was no longer significant. At 28 and 35 DAT, neither the main effects nor the interaction effects reached statistical significance, indicating that treatment effects on height were most pronounced during the early vegetative growth phase.

The mean separation tests revealed specific patterns of treatment responses. At 14 DAT, the P <ts> T <ts> combination (120 ml/L POC + 20 g Trichoderma) produced the greatest plant height 9.63 cm, significantly exceeding all other treatments. The P_1 level of POC (120 ml/L) produced an average height of 8.90 cm across Trichoderma levels, significantly greater than P_0 (8.12 cm) and numerically greater than P_2 (8.66 cm). For Trichoderma main effects, both T_1 and T_2 produced equal mean heights of 8.90 cm, both significantly exceeding T_0 (7.88 cm). At 21 DAT, both P_1 and P_2 (7.22 and 7.39 cm respectively) significantly exceeded P_0 (3.33 cm), while T_1 and T_2 (6.67 and 6.90 cm) both exceeded T_0 (4.38 cm). The combination treatment P <cm> T <cm> continued to show superior performance at 8.40 cm. However, at 28 and 35 DAT, the differences among treatments were no longer statistically significant, despite numerical variation.

Table 3. Soil Nutrient Status in Growth Media by Treatment

Treatment	Total Nitrogen (%)	Available Phosphorus (ppm)	Exchangeable Potassium (me/100g)
P_0T_0	0.25	4.12	0.30

Treatment	Total Nitrogen (%)	Available Phosphorus (ppm)	Exchangeable Potassium (me/100g)
P_0T_1	0.28	1.41	0.68
P_0T_2	0.31	14.72	0.95
P_1T_0	0.32	2.89	0.4

The significant positive effects of POC on plant height during the early growth stages can be attributed to multiple mechanisms. Although modest in concentration, nitrogen supplied by POC contributed to chlorophyll synthesis, protein production, and cell division, which are all essential for stem elongation. More importantly, cytokinins naturally present in moringa leaf extract exert direct effects on meristematic activity, stimulating cell division and cell expansion in apical meristems. Studies have demonstrated that exogenous cytokinin application increases plant height by enhancing both cell production and cell size in elongation zones. The periodic application of POC every three days throughout the growth period maintained a relatively consistent hormone supply and sustained growth stimulation. The optimal effect at the P_1 level (120 ml/L) compared to P_2 (220 ml/L) suggests a dose-response relationship with a plateau or even decline at higher concentrations, possibly due to hormone imbalance or excessive nitrogen causing soft, weak growth rather than sturdy development.

Trichoderma affects plant height through distinct but complementary mechanisms. Trichoderma colonization of roots stimulates auxin and gibberellin production, hormones that promote cell elongation and stem growth. Enhanced nutrient acquisition through improved root development and increased nutrient availability from organic matter decomposition provide the metabolic resources necessary for rapid growth. The similar effects of T_1 and T_2 dosages suggest that 20 g per polybag was sufficient to achieve a maximum height response, with additional inoculum providing no further benefit. The significant interaction effect at 14 DAT indicated a synergistic relationship between POC and Trichoderma during early establishment. POC applications may have stimulated Trichoderma activity by providing readily available carbon sources, whereas Trichoderma enhanced POC-derived nutrient availability through enzyme production and root development, collectively producing effects exceeding those of either input alone.

The diminishing treatment effects on height at later growth stages (28 and 35 DAT) reflected biological and developmental factors. As lettuce transitions from the juvenile to mature vegetative phases, growth allocation shifts from vertical stem elongation to lateral leaf expansion and biomass accumulation. The genetically determined rosette growth habit of lettuce limits the ultimate height, and once plants approach maturity, further height increases are minimal, regardless of nutrition or management. Additionally, the relatively short-term effects of POC applications may have been exhausted by late growth stages, particularly under warm tropical conditions that accelerate mineralization and microbial activity. The absence of interaction effects at later stages suggests that any synergistic benefits between POC and Trichoderma are primarily expressed during the critical early establishment period.

Statistical analysis of leaf number revealed distinct patterns, with treatment effects becoming significant only at the later growth stages. No significant effects of POC, Trichoderma, or their interactions were detected 14, 21, or 28 DAT. However, at 35 DAT, POC showed significant main effects ($P < 0.05$), and Trichoderma showed highly significant effects ($P < 0.01$), although the interaction remained non-significant. This delayed response contrasts with early stage height effects, suggesting differential timing of treatment impacts on different growth parameters.

The mean values and mean separation revealed the nature of the responses. Although not statistically significant at early stages, numerical trends showed P_1 and P_2 generally producing more leaves than P_0, and T_2 typically exceeding T_1 and T_0. By 35 DAT, when the differences became significant, P_1 produced an average of 2.11 leaves (during the measurement interval), significantly exceeding P_0 (1.33 leaves) and numerically greater than P_2 (1.56 leaves). For Trichoderma, T_2 produced 2.33 leaves, significantly exceeding both T_1 (1.78 leaves) and T_0 (0.89 leaves). The combination treatment P_1T_2 yielded the highest leaf production at 2.67 leaves, substantially greater than the control P_0T_0 (0.00 leaves during this interval).

The delayed manifestation of treatment effects on leaf number compared to plant height reflects the fundamental aspects of leaf developmental physiology. Leaf initiation occurs in the shoot apical meristem where leaf primordia are formed sequentially at regular intervals. The rate of leaf initiation depends on meristem activity, which is influenced by the hormonal balance, nutritional status, and environmental conditions. Following initiation, individual leaves undergo expansion through cell division and enlargement before becoming visible for counting. This sequence creates a temporal lag between treatment application and observable effects on the leaf number. Early stage treatments primarily influenced processes affecting already-initiated leaves (contributing to height responses), whereas impacts on leaf initiation rates became apparent only after sufficient time for newly formed primordia to develop into countable leaves.

The significant positive effects of POC on leaf number at 35 DAT can be attributed to the cytokinin-mediated promotion of lateral meristem activity and suppression of apical dominance. Cytokinins stimulate the formation and outgrowth of axillary buds, thereby increasing branching and leaf production. In lettuce, which has a rosette growth habit, this translates to a greater number of leaves on the central rosette. Nitrogen supply from POC also contributes by providing essential building blocks for protein synthesis in rapidly dividing meristematic tissues. The periodic application schedule maintained hormone and nutrient availability throughout the growth period, thereby sustaining leaf initiation and development. The P_1 level again proved optimal, reinforcing the existence of an optimal application rate balancing stimulation and potential inhibition at excessive levels.

Trichoderma effects on leaf number likely operate through enhanced resource availability, supporting the metabolically expensive processes of leaf initiation and expansion. Improved nutrient acquisition through enlarged root systems and increased mineralization provide the mineral nutrition necessary for rapid tissue formation. Phytohormone production by Trichoderma spp, particularly cytokinins, may directly stimulate leaf primordium formation. The greater effectiveness of T_2 compared to T_1 for leaf number contrasts with the similar effects on height, suggesting that different Trichoderma functions (root modification, nutrient mobilization, and hormone production) may have differential dose-response relationships for various plant processes. Higher T_2 dosage may have

Resulted in more extensive root colonization or higher rhizosphere enzyme activities, translating to improved nutrient status supporting leaf production.

The non-significant interaction effects throughout the observation period indicated that POC and Trichoderma effects on leaf number were largely additive rather than synergistic. Each input contributed independently to leaf production through distinct mechanisms (POC via direct hormone supply and some nutrition, Trichoderma via root enhancement and nutrient mobilization), with combined applications producing cumulative rather than multiplicative benefits. This additive relationship provides practical value by allowing the optimization of each input independently, without complex interactive management requirements.

Analysis of variance for leaf length showed significant treatment effects at the early to mid-growth stages, but diminished effects on maturity. At 14 DAT, Trichoderma exhibited highly significant effects ($P < 0.01$), whereas POC and the interaction were not significant. At 21 DAT, both Trichoderma ($P < 0.01$) and POC ($P < 0.05$) showed significant effects, with the interaction remaining non-significant. At 28 and 35 DAT, no treatment effects reached statistical significance, indicating that treatment influences on individual leaf size were most pronounced during the active leaf expansion phases.

Mean separation at 14 DAT revealed that Trichoderma application significantly increased leaf length, with T <ts> producing the longest leaves (3.68 cm) among the main effect treatments. The P <ns> T <ns> combination yielded 4.20 cm, the greatest among all combinations. At 21 DAT, both T_1 (3.68 cm) and P_1 treatments showed superior performance. However, at 28 and 35 DAT, although the numerical differences persisted, statistical significance was lost, paralleling the patterns observed for height and leaf number.

The early significant effects of Trichoderma on leaf length highlight the importance of root system development in supporting rapid leaf expansion. Leaf expansion is a cell enlargement process that is heavily dependent on water uptake driven by osmotic gradients, with cell wall extensibility and turgor pressure determining the ultimate cell and organ size. Trichoderma-enhanced root systems provide a greater capacity for water and mineral uptake, supporting the metabolic processes underlying cell expansion. Improved nutrient acquisition, particularly nitrogen for protein synthesis and potassium for osmoregulation, further facilitates leaf growth. Phytohormones produced by Trichoderma, particularly auxins, directly stimulate cell expansion in leaf tissues, contributing to increased leaf dimensions.

POC effects on leaf length, although somewhat delayed compared to Trichoderma, reflect combined nutritional and hormonal influences. Nitrogen and other nutrients support the biosynthesis of cellular components that are necessary for leaf tissue formation and expansion. Cytokinins in moringa extract promote cell division in leaf primordial stages, thereby increasing cell number and potential leaf size. The delayed effect compared to Trichoderma may reflect the time required for repeated POC applications to accumulate sufficient nutrients and hormones to significantly impact leaf expansion, whereas Trichoderma root effects manifested more rapidly once colonization was established.

The loss of significant treatment effects on leaf length at later growth stages reflects developmental transition. As leaves approach genetic size limits and as plants increasingly allocate resources toward reproduction (even though not yet flowering, internal signaling may begin shifting resource allocation patterns), treatment-induced differences in leaf expansion capacity become less apparent. Environmental factors, including warm lowland temperatures, may also have constrained the maximum attainable leaf size regardless of nutrition, as high temperatures can limit cell expansion through effects on cell wall properties and water relations.

Statistical analysis of leaf width showed intermediate patterns between leaf length and leaf number. At 14 and 21 DAT, Trichoderma showed significant main effects ($P < 0.05$), whereas POC effects were not significant. At 28 DAT, neither the main effects nor interactions were significant. At 35 DAT, no significant effects were observed. These patterns indicated that Trichoderma was the primary driver of leaf width responses, with effects concentrated in the early growth stages.

Mean values and statistical groupings showed that T_2 and T_1 generally produced wider leaves than T_0, with T_2 often showing slight numerical superiority over T_1. POC levels showed less consistent patterns, with P < ce > often performing well, but the differences did not reach statistical significance. The combination P_1T_2 frequently showed the greatest leaf width among treatment combinations, though interaction effects were not statistically significant. At 14 DAT, the T_2 level achieved a mean width of 4.78 cm while T_0 produced 4.51 cm, with P_1T_2 reaching 5.80 cm individually.

Leaf width, such as leaf length, depends fundamentally on cell expansion processes supported by adequate water and nutrient supply. The consistently significant effects of Trichoderma, particularly at higher dosages (T_2), emphasize the importance of robust root systems for achieving maximum leaf dimensions. Enhanced nutrient acquisition through Trichoderma-mediated root development and organic matter decomposition provides mineral resources necessary for the synthesis of cell wall materials, proteins, and other structural components that determine leaf size. Potassium, which showed elevated levels in Trichoderma-treated media, played a critical role in osmoregulation and cell expansion, potentially contributing to the observed increase in width.

The somewhat greater response of leaf width to Trichoderma compared to POC contrasts with the patterns for other growth parameters, where both inputs often showed significant effects. This differential response may be related to the spatial and temporal dynamics of the leaf development. Leaf width is largely determined during the later stages of leaf expansion, when already-formed cells undergo final enlargement. At these stages, the capacity for resource acquisition (enhanced by Trichoderma-improved roots) may be more limited than the availability of specific nutrients or hormones (supplied by POC). Additionally, auxins produced by Trichoderma specifically promote cell enlargement, the primary process determining leaf width, whereas cytokinins from moringa extract strongly influence cell division and organ initiation.

Discussion

Analysis of variance for fresh weight at harvest revealed highly significant effects for both the main factors and their interactions. POC showed highly significant effects ($P < 0.01$), Trichoderma exhibited significant effects ($P < 0.05$), and the interaction between POC and Trichoderma was highly significant ($P < 0.01$). These strong statistical effects on the ultimate yield parameter indicate that cumulative treatment impacts throughout the growth cycle translate to substantial differences in the harvestable biomass.

Mean separation revealed that the P_1 level (120 ml/L POC) produced the greatest fresh weight among POC treatments (13.67 g), significantly exceeding both P_0 (8.67 g) and P_2 (8.00 g). For Trichoderma, both T_1 and T_2 (11.44 and 11.00 g respectively) significantly exceeded T_0 (7.89 g). The interaction analysis showed that P_1T_1 produced the highest fresh weight at 17.67 g, followed closely by P_1T_2 at 15.67 g. Both of these combinations far exceeded the control P_0T_0 (7.67 g), representing increases of 130% and 104% respectively. Notably, the high POC level P_2 did not enhance yield and in some combinations appeared inhibitory compared to P_1.

The highly significant treatment effects on fresh weight integrate cumulative effects throughout the entire growth cycle. Fresh weight represents the total photosynthetic productivity modified by respiration and allocation patterns, synthesizing information about plant growth capacity, resource acquisition, and biomass accumulation efficiency. The significant interaction effect indicated that the combined application of POC and Trichoderma produced synergistic yield benefits exceeding the additive expectations from individual inputs. This synergy likely reflects complementary mechanisms: POC provided readily available nutrients and hormonal signals stimulating photosynthetic capacity and growth rates; Trichoderma enhanced root function and nutrient mobilization, ensuring that plants could fully utilize available resources; and the combination optimized both resource supply and plant capacity for growth.

The optimal POC level at 120 ml/L (P_1) rather than 220 ml/L (P_2) for fresh weight mirrors patterns observed for most vegetative parameters, reinforcing the conclusion that excessive POC application can be counterproductive. Several mechanisms may explain this non-linear dose-response. First, excessive nitrogen from high POC rates may promote vegetative growth at the expense of efficient biomass accumulation, creating lush but metabolically inefficient foliage. Second, salt accumulation from repeated high-concentration applications can create osmotic stress, particularly in container-grown plants with restricted soil volume. Third, excessive cytokinin concentrations may disrupt the optimal hormonal balance, potentially causing abnormal growth patterns or inhibiting certain developmental processes. Fourth, high organic acid concentrations in fermented POC could temporarily suppress the soil pH below optimal levels for nutrient availability.

The substantial increase in fresh weight from Trichoderma treatments underscores the importance of root system optimization for yield. Although the effects of Trichordema on individual vegetative parameters were sometimes modest or inconsistent, the cumulative impact on total biomass was pronounced. This pattern suggests that the effects of Trichoderma that extended throughout the growth cycle were integrated into superior overall plant performance. Improved nutrient and water acquisition capacity sustained by Trichoderma-enhanced roots supported continuous photosynthetic activity and biomass accumulation. Disease suppression, although not directly measured in this pathogen-free experiment, may have contributed to the maintenance of root health and function throughout the growth period. The similar effectiveness of T_1 and T_2 levels for fresh weight, despite some differences in the effects on individual parameters, suggests that 20 g per polybag achieved near-maximum colonization and beneficial effects, with additional inoculum providing limited further advantage.

The superior performance of combination treatments, particularly P_1T_1 and P_1T_2, validates the integrated approach to organic nutrient management. The synergistic effects demonstrate that optimizing both above ground (through POC-supplied nutrients and hormones) and below ground (through Trichoderma-enhanced root function) aspects of plant nutrition produces results exceeding what either strategy achieves independently. From a practical perspective, these combinations represent economically viable approaches for organic lettuce production, achieving substantial yield improvements through relatively low-cost inputs derived from locally available materials (moringa leaves) and biological agents that require minimal infrastructure.

This study demonstrates that the integrated application of moringa leaf liquid organic fertilizer and Trichoderma significantly enhances lettuce growth and productivity through complementary mechanisms operating at multiple biological scales. At the cellular level, cytokinins and other phytohormones in moringa extract stimulate meristematic activity, promoting cell division and expansion that drives plant growth. At the organ level, Trichoderma colonization modifies the root architecture, increasing the surface area and acquisition capacity for water and nutrients. At the whole-plant level, these effects integrate into enhanced photosynthetic capacity, efficient resource utilization, and ultimately superior biomass accumulation, manifested as increased fresh weight yield.

The temporal dynamics of treatment effects provide important insights for management optimization. Early stage responses (height and leaf length) manifested rapidly, within 14-21 days of treatment initiation, suggesting that establishment conditions and early nutrition critically influence vegetative trajectory. Later-maturing responses (leaf number and fresh weight) required an extended time for expression, highlighting the importance of sustained treatment throughout the growth cycle. The diminishing treatment effects on individual parameters at late growth stages, in contrast with strong cumulative effects on fresh weight, emphasize the value of sustained rather than pulse inputs in vegetable production systems.

The optimal POC concentration identified at 120 ml/L rather than the 220 ml/L tested, provides practical guidance for application rates. The dose-response pattern, with a clear optimum followed by a decline at higher concentrations, emphasizes the importance of balanced nutrition over maximum input levels. This finding aligns with horticultural principles, which recognize that excessive nutrient availability can be as detrimental as deficiency, particularly for intensive vegetable crops grown in restricted root volumes. Farmers adopting moringa-based POC should carefully calibrate application rates, potentially through preliminary trials under their specific conditions, to avoid over-application that wastes inputs and reduces rather than enhances performance.

The effectiveness of both Trichoderma dosage levels tested (20 and 30 g per polybag) suggests some flexibility in inoculum rates, although the lower levels often achieved equivalent or superior results. From an economic perspective, using the minimum effective dose maximizes return on investment. However, environmental factors, including soil type, temperature, moisture, and indigenous microbial communities, influence Trichoderma establishment and activity, suggesting that optimal rates may require adjustments across different production contexts. The pre-planting application strategy employed here facilitated Trichoderma colonization before the roots became extensive, likely contributing to the treatment effectiveness. Alternative application timing and methods warrant investigation to refine these recommendations.

The synergistic interactions between POC and Trichoderma were documented for fresh weight and suggested by interaction effects on plant height, validating integrated approaches combining multiple beneficial inputs. These synergies arise from complementary mechanisms: organic fertilizers provide substrates supporting microbial activity while supplying plant nutrients and hormones; Trichoderma accelerates organic matter decomposition, enhancing nutrient availability while simultaneously improving root function; and the combination optimizes both resource supply and plant capacity for growth. These principles extend beyond the specific inputs tested herein, suggesting that the integration of diverse organic amendments, biostimulants, and beneficial microorganisms represents a promising paradigm for sustainable intensive vegetable production.

From an environmental sustainability perspective, the demonstrated effectiveness of Moringa POC and Trichoderma offers pathways to reduce synthetic fertilizer dependency in vegetable production. Moringa trees grow rapidly with minimal input and can be cultivated on marginal lands unsuitable for other agriculture, making them accessible resources, even for smallholder farmers. Local production of POC from farm-grown moringa reduces external input costs, while recycling nutrients within the farm system. Similarly, Trichoderma can be multiplied on simple substrates using basic equipment to facilitate on-farm or community-level production. The dual benefits of improved crop productivity and reduced environmental impact position these technologies to favorably promote sustainable agricultural initiatives.

Economic analysis, although beyond the scope of this research, merits consideration for adoption decisions. POC production requires labor for harvesting moringa leaves, processing, and fermentation, along with costs for sugar, coconut water, and microbial inoculants. Trichoderma costs include the purchase of an initial inoculant (although on-farm multiplication can reduce recurring costs). These input costs must be weighed against yield benefits, market prices for lettuce, and premium prices for organically produced vegetables. The substantial yield increases documented here (up to 130% improvement with optimal treatments) suggest favorable economic returns; however, site-specific economic analysis should be conducted considering local cost structures and market conditions.

4. CONCLUSIONS AND SUGGESTIONS

This study systematically evaluated the interactive effects of liquid smoke and rice-husk biochar amendments on shallot growth and production under controlled experimental conditions. The central finding that the combined application of liquid smoke at 70 ml/L concentration with biochar at 300 g/polybag produced substantially enhanced bulb production parameters (50% weight increase, 38% bulb number increase relative to control treatments) provides evidence-based justification for integrated amendment protocols in shallot cultivation. While early vegetative growth parameters (plant height and leaf number) showed minimal treatment effects, the pronounced impacts on bulb production (the economically critical parameter) substantiated the practical value of this amendment approach. The concentration-dependent biphasic response to liquid smoke—optimal effects at 70 ml/L and diminished effects at 90 ml/L underscores the necessity for precision in amendment application. The synergistic interaction between organic biostimulants and physical soil amendments represents an important direction for sustainable intensification of vegetable production systems. Future investigations should extend the observation period to capture long-term biochar effects, examine variable soil types and climatic conditions, and investigate the optimal timing of amendment application during the cultivation cycle. The implementation of these findings will contribute to agricultural sustainability objectives through reduced chemical input dependency while maintaining or exceeding yields achievable through conventional production methodologies. This approach holds promise for resource-limited producers seeking to enhance productivity within environmentally compatible frameworks.

5. ACKNOWLEDGE

The authors thank all the people and institutions in most cases who helped and funded this research.

6. REFERENCE

Adelina, R., Harahap, S., Amnah, R. Nasution, Y. (2023). *Bimbingan Teknis Kelompok Tani Pembuatan Mikroorganisme Lokal (MOL) Dan Pupuk Organik Cair (POC) Di Kota Padangsidimpuan. BEST Journal (Biology Education, Sains and Technology), 6(2), pp.373-379.*

Arikunto, S. (2016). *Metodologi Penelitian Suatu Pendekatan Proposal. Jakarta: Rineka Cipta.*

Badan Pusat Statistik. (2022). *Kabupaten Padang Lawas Dalam Angka. Badan Pusat Statistik Padang Lawas.*

Creswell, J. W. (2021). *Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). SAGE Publications.*

Mare.T.W., Gresinta E., & S. N. (2022). *Efektivitas Pupuk Organik Cair Daun Kelor (Moringa oleifera) terhadap Pertumbuhan Tanaman Bawang Daun (Allium fistulosum L.) Jurnal EduBiologi*.

Medina LI, Bertolín JR., D. A. (2021). *Nutritional value of commercial and traditional lettuce (Lactuca sativa L.) and wild relatives: Vitamin C and anthocyanin content. Food Chemistry*. https://doi.org/10.1016/j.foodchem. 2021.129864

Paulina, M., Lumbantoruan, S. M., & Septiani, A. . (2020). *Potensi Pemanfaatan Limbah Air Cucian Beras Pada Tanaman Pakcoy (Brassica Rapa L.). Jurnal Agroteknologi Dan*

Pertanian (JURAGAN), 1(1), 17–24.

Saragih Evi Warintan, Purwanigsih, P., Noviyanti, & Angelina Tethool. (2021). Pupuk Organik Cair Berbahan Dasar Limbah Ternak untuk Tanaman Sayuran. *Dinamisia : Jurnal Pengabdian Kepada Masyarakat*, *5*(6), 1465–1471. https://doi.org/10.31849/dinamisia.v5i6.5534

Sari, S. W., Safruddin, & Purba, D. W. (2019). *Pengaruh Pemberian Ekstrak Daun Kelor dan Nutrisi Ab-Mix Terhadap Pertumbuhan dan Produksi Tanaman*.

Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D. Bandung Alfabeta*.

Suhastyo, A. asriyanti, & Raditya, F. T. (2021). PENGARUH PEMBERIAN PUPUK CAIR DAUN KELOR DAN CANGKANG TELUR TERHADAP PERTUMBUHAN SAWI SAMHONG (Brassica juncea L.). *Jurnal AGROSAINS Dan TEKNOLOGI*, *6*(1), 1–6. https://doi.org/10.24853/jat.6.1.1-6

Tomia, L. M., & Pelia, L. (2021). PENGARUH PUPUK ORGANIK CAIR DAUN KELOR TERHADAP PERTUMBUHAN DAN HASIL TANAMAN TERONG UNGU. *Jurnal Ilmiah Mahasiswa Fakultas Pertanian*, *1*(3), 77–81. https://doi.org/10.52045/jimfp.v1i3.193

Widyarti, N. M. P., dan Tambing, Y. (2023). *Pengaruh Berbagai Konsentrasi Pupuk Organik Cair Daun Kelor Terhadap Pertumbuhan Dan Hasil Tanaman Mentimun (Cucumis sativus L.).*

Yani, D. A., Juliansyah, H., Puteh, A., & Anwar, K. (2022). *Minimalisasi Biaya Produksi Usaha Tani Melalui Pemanfaatan Limbah Buah-buahan Sebagai Pupuk Organik cair. Jurnal Malikussaleh Mengabdi, 1(2), 01*. https://doi.org/10.29103/jmm.v1i 2.8237