Available at : https://ejournal.unib.ac.id/index.php/terrajournal ISSN 2621-0207
DOI : https://doi.org/10.31186/terra.8.2.105-113

TERRA
Journal of Land Restoration

Effect of Different Concentration of Liquid Organic Fertilizer and Varieties on The Growth and Yield of Red Chili (*Capsicum annuum* L.) in Sandy Soil

Andre Setiyawan[1], Sri Devi Octavia[2*]

[1]*Department of Agrotechnology, Faculty of Agriculture, Universitas Tamansiswa Palembang, Indonesia*
[2]*Department of Agronomy, Faculty of Agriculture, Universitas Sam Ratulangi, Indonesia*

Corresponding Author : sdevioctavia@unsrat.ac.id

ABSTRACT

Sandy soils, characterized by high sand content (often exceeding 70-90%), exhibit low nutrient retention, poor water-holding capacity, and reduced cation exchange due to their coarse texture and low organic matter. These properties pose significant challenges for red chili (Capsicum annuum L.) cultivation, often resulting in suboptimal growth and yield without amendments. This study aimed to evaluate the effects of varying concentrations of liquid organic fertilizer derived from vinasse and different red chili varieties on the growth and yield of red chili plants in such challenging soil conditions. The experiment was conducted in a greenhouse at the Faculty of Agriculture, Sarjanawiya Tamansiswa University, Yogyakarta. A 3 × 2 factorial design arranged in a Completely Randomized Design (CRD) with four replications was employed. The first factor consisted of liquid organic fertilizer concentrations at 5%, 6%, and 7%, while the second factor included two red chili varieties: F1 Gada and Prabu. Growth parameters measured were plant height, number of leaves, stem diameter, and number of branches. Yield components included fresh and dry plant weight, number of fruits, and fresh fruit weight. The results indicated no significant interaction between fertilizer concentration and chili variety on growth and yield parameters. However, the F1 Gada variety exhibited significantly greater fresh plant weight and number of fruits compared to Prabu. These findings suggest that selecting appropriate chili varieties, such as F1 Gada, combined with optimal liquid organic fertilizer concentration, can improve red chili production in sandy soils. This information is valuable for farmers and agricultural practitioners aiming to enhance cultivation efficiency and yield within sustainable farming systems.

Keywords: liquid organic fertilizer, red chili, varieties, vinasse

INTRODUCTION

Red chili (*Capsicum annuum* L.) is one of the most widely consumed vegetable commodities in Indonesia. Its popularity is attributed not only to its characteristic pungency, derived from the alkaloid capsaicin, but also to its nutritional value, including vitamins C, B1, B2, and essential minerals such as calcium and phosphorus (Agustina *et al*., 2014; Alsebaeai *et al*., 2020). In 2023, the average per capita consumption of red chili in Indonesia reached approximately 3,000 g per year. With the national population projected to reach 284 million in 2025, the annual demand for red chili is estimated at 850,000 tons (BPS, 2024). This increasing demand is expected to continue as population growth and agro-industrial development progress.

To meet the rising demand, various technological innovations have been introduced to improve chili production, particularly the use of organic fertilizers and the cultivation of high-yielding varieties. As cultivated areas expand, fertilizer use becomes increasingly intensive. Although chemical fertilizers can rapidly enhance plant growth and yield, their prolonged use may degrade soil quality. In contrast, organic fertilizers support long-term soil health. They improve soil structure, increase humus content, enhance microbial activity, promote water retention, reduce erosion and nitrogen leaching, and improve cation exchange capacity (Verma *et al*., 2019; Yan *et al*., 2021; Zhang *et al*., 2024; Luo *et al*., 2022; Samputri *et al*., 2023). Thus, integrating organic fertilization practices is a promising approach for sustaining soil fertility and ensuring long-term agricultural productivity.

Organic fertilizers are generally available in solid and liquid forms. Liquid organic fertilizers, derived from the decomposition of plant residues and animal

or human wastes, are known for their relatively high nutrient availability (Suhastyo, 2019; Rohcahyani *et al*., 2025). In this study, the liquid organic fertilizer used was vinasse, which had undergone a composting process prior to application. Vinasse is a residual by-product generated during ethanol production from sugarcane and sugar beet. It is characterized by a dark coloration, acidic pH, high electrical conductivity, and elevated organic matter content. In addition, vinasse contains substantial amounts of suspended and volatile solids and may also contain trace concentrations of heavy metals (Wulandari *et al*., 2023; Carrilho & Soares, 2024). Potassium (K) is the dominant mineral in vinasse, ranging from 6.36% to 7.2% per 100 g, exceeding other minerals such as sodium (1.58–1.84%) and phosphorus (0.24–0.28%). Vinasse also provides a range of macroelements (K, Ca, Mg, P, and N) and microelements such as Fe, Zn, Mn, Cu, Pb, and Al (Scull *et al*., 2012; Lourenço *et al*., 2022).

Beyond nutrient management, the selection of suitable varieties is equally crucial for improving chili production. Varietal selection is a central component of cultivation technology, influencing growth performance, yield potential, and economic returns. Each variety carries distinct genetic characteristics that determine its adaptability to environmental conditions, growth capacity, and productivity. Superior varieties can significantly enhance crop yield and overall quality (Aryawati *et al*., 2021).

Given the importance of both nutrient inputs and genetic factors, this study aimed to evaluate the effects of vinasse-based liquid organic fertilizer and different chili varieties under greenhouse conditions. Specifically, the research assessed how varying concentrations of vinasse and the choice of variety influence the growth and yield of red chili plants (*Capsicum annuum* L.).

MATERIALS AND METHODS

This research was carried out from November 2021 to February 2022 in the greenhouse of the Faculty of Agriculture, Sarjanawiyata Tamansiswa University, Yogyakarta. The materials used included seeds of two red chili varieties (Gada F1 and Prabu), liquid organic fertilizer derived primarily from vinasse and enriched with gamal leaves, and a planting medium composed of charcoal husks, sand, and compost. The tools employed consisted of polybags, a hoe, ruler, shovel, measuring cup, bucket, writing instruments, camera, scale, caliper, and an oven.

The study was arranged using a 3 × 2 factorial experiment within a Completely Randomized Design (CRD), with four replications. The first factor was the concentration of liquid organic fertilizer, consisting of three levels: 5% (B_1), 6% (B_2), and 7% (B_3). The second factor was the red chili variety, comprising Gada F1 (V_1) and Prabu (V_2). The six treatment combinations were as follows: B_1V_1 (5% fertilizer + Gada F1), B_1V_2 (5% fertilizer + Prabu), B_2V_1 (6% fertilizer + Gada F1), B_2V_2 (6% fertilizer + Prabu), B_3V_1 (7% fertilizer + Gada F1), and B_3V_2 (7% fertilizer + Prabu).

The planting medium was prepared by mixing sand, charcoal husks, and compost in a 1:1:1 ratio, which was then placed into polybags measuring 40 cm × 40 cm. Liquid organic fertilizer was diluted according to the treatment levels: 5% (50 mL per 1000 mL of water), 6% (60 mL per 1000 mL of water), and 7% (70 mL per 1000 mL of water). Each plant received 55 ml of the diluted solution every four days.

Observations included plant height, number of leaves, stem diameter, number of branches, fresh and dry plant weight, number of fruits, and fruit fresh weight. Data were analyzed using Analysis of Variance (ANOVA) at a significance level of $\alpha = 0.05$. When significant differences were found, Duncan's Multiple Range Test (DMRT) was applied to compare treatment means.

RESULTS AND DISCUSSION

The results showed that there was no interaction between the treatment of liquid organic fertilizer concentration made from vinasse and varieties on the variables of plant height, number of leaves, stem diameter, number of branches, number of fruits per plant, fresh weight of fruits per plant, fresh weight of plants, and dry weight of plants on red chili plants. The doses of liquid fertilizer are 5%, 6%, and 7% per liter of water, and the varieties of chili are Gada F1 and Prabu.,

Table 1 indicates that there is no significant interaction between the concentrations of liquid organic fertilizer derived from vinasse and the varieties of red chili plants concerning plant height. The application of liquid organic fertilizer at concentrations of 5%, 6%, and 7% did not result in significant differences in plant height. This outcome is likely attributable to the limited availability of nutrients in vinasse-based liquid organic fertilizer. Essential macronutrients such as nitrogen (approximately 4.5%), phosphorus (around 0.3% as P_2O_5), and potassium (about 6% as K_2O) are present but may be in insufficient quantities to promote optimal plant growth.

Table 1. Mean plant height (cm) at 45 days for different concentrations and varieties

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	34.09	23.04	28.56 a
K_2 (6%)	29.13	28.19	28.66 a
K_3 (7%)	21.97	25.33	23.65 a
Mean	28.40 p	25.52 p	26.86 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

Deficiencies in these macronutrients can impede plant growth and development by disrupting cell formation, reducing photosynthesis, and slowing both vegetative and reproductive phases. Nitrogen plays a critical role in the synthesis of nucleic acids, enzymes, proteins, and chlorophyll, all of which are crucial during vegeta-tive growth and development (Shrivastaav *et al*., 2020; Shah *et al*., 2024; Chrysargyris & Tzortzakis, 2025). Potassium is involved in starch synthesis, enzyme activation, regulation of physiological processes, and enhancement of resistance to drought stress and diseases (Hasanuzzaman *et al*., 2018; Sardans & Peñuelas, 2021). According to Sinha & Tandon (2020) and Tariq *et al*. (2023), low availability of nitrogen and phosphorus in the soil results in reduced growth rates and stunted plants.

Furthermore, no significant differences in plant height were observed between the Gada F1 and Prabu varieties, which likely reflects genetic factors affecting their adaptability to environmental conditions and inherent growth

Table 2 reveals no significant interaction between concentrations of liquid organic fertilizer derived from vinasse and red chili varieties with respect to the number of leaves. Application of this fertilizer at 5%, 6%, and 7% concentrations yielded no statistically significant differences in leaf number. This result likely stems from the limited availability of essential macronutrients—nitrogen (approximately 2.87%), phosphorus (0.33%), and potassium (0.35%) particularly during early vegetative stages, as vinasse-based formulations often provide these in sub-optimal quantities.

Table 2. Mean of number of leaves 45 days after planting

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	18.08	14.08	16.08 a
K_2 (6%)	14.50	17.91	16.20 a
K_3 (7%)	10.83	16.91	13.87 a
Mean	14.47 p	16.30 p	15.38 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significance with α 5% (n = 3)

Nitrogen is essential for leaf development, facilitating chlorophyll, protein, and lipid synthesis critical for photosynthesis and overall growth (Wibowo, 2021). Inadequate nutrient supply constrains chlorophyll formation, thereby diminishing photosynthetic capacity and restricting vegetative expansion. No significant differences in leaf number occurred between Gada F1 and Prabu varieties, attributable to genetic variability influencing phenotypic traits like leaf production, consistent with findings that varietal characteristics markedly affect leaf number and yield potential (Yulina *et al.,* 2021).

Table 3 demonstrates no significant inter-action between the concentrations of liquid organic fertilizer derived from vinasse and the red chili varieties tested in terms of stem diameter measured 45 days after planting. The application of liquid organic fertilizer at 5%, 6%, and 7% concentrations did not result in a statistically significant increase in stem diameter. This suggests that the nutrient levels available, particularly phosphorus, in the fertilizer were insufficient to trigger a physiological response necessary for stem thickening.

Phosphorus is essential for plant tissue development, especially for stem growth, by supporting protein synthesis required for cell division and formation critical processes in increasing stem diameter. Phosphorus also plays a vital role in energy transfer through ATP synthesis, strengthening stalks and stems, and promoting root development, which enhances overall plant vigor (Raghothama, 1999; Vance *et al.,* 2003; Lynch, 2011). Studies have reported that phosphorus facilitates stem growth by promoting cell

division, and higher fertilizer concentrations could be necessary to stimulate significant stem dia-meter increases in red chili plants (Yulina *et al*., 2021).

Furthermore, no significant difference in stem diameter was observed between the Gada F1 and Prabu varieties, indicating a similar genetic potential for stem thickness under the tested conditions. This finding suggests that varietal differences in stem diameter may be minimal in this experimental context. This synthesis integrates the nutrient limitation hypothesis with phosphorus's recognized physiological roles to explain the observed lack of significant stem diameter response.

Table 3. Mean of stem diameter (mm) at 45 days after planting for different concentrations and varieties

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	0.48	0.35	0.42 a
K_2 (6%)	0.40	0.40	0.40 a
K_3 (7%)	0.32	0.40	0.36 a
Mean	0.40 p	0.38 p	0.39 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

Table 4 shows that there was no significant interaction between the concentrations of liquid organic fertilizer derived from vinasse and the red chili varieties tested. The absence of a significant effect is primarily attributed to the relatively low macronutrient content particularly nitrogen (N), phosphorus (P), and potassium (K)—in the liquid organic fertilizer formulation. This finding aligns with the results of Arrodli *et al*. (2011), who reported that vinasse did not significantly affect the vegetative phase of sugarcane but mainly improved soil physical properties. Vinasse enhances soil health by increasing water retention, adding organic carbon, and facilitating nutrient uptake by plants (Zikeli *et al*., 2017; da Silva *et al*., 2021; Friedrichsen *et al*., 2021; Jia *et al*., 2021). Furthermore, vinasse improves soil structure by increasing porosity and promoting the growth and activity of beneficial soil microorganisms (Hossain *et al*., 2016; Nathaniel *et al*., 2020; Garbowski *et al*., 2023).

The Gada F1 variety exhibited a significantly higher fresh plant weight (5.33 g) compared to the Prabu variety (2.52 g). This difference is attributed to genetic factors influencing branching, with the Gada F1 variety possessing superior genetic traits for vegetative growth that result in increased branching. In conclusion, although vinasse-based liquid organic fertilizer may not supply sufficient macronutrients to directly enhance biomass accumulation, it plays a vital role in improving soil health and indirectly supporting plant growth. Genetic variation among varieties substantially affects morphological traits such as branch number and fresh weight. Therefore, optimizing red chili production requires both balancing fertilizer nutrient content and selecting superior genotypes.

Table 4. Mean of number of branches for different concentrations and varieties

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	4.83	2.91	3.87 a
K_2 (6%)	5.75	2.50	4.12 a
K_3 (7%)	5.41	2.16	3.79 a
Mean	5.33 p	2.52 q	3.93 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

Table 5 indicates no significant interaction between the concentration of vinasse-based liquid organic fertilizer and the red chili varieties tested. The application of liquid organic fertilizer at 5%, 6%, and 7% concentrations did not produce statistically significant differences in fresh plant weight. This outcome likely results from the limited nutrient availability in vinasse-based fertilizer, where essential macronutrients such as nitrogen (approximately 4.5%), phosphorus (around 0.3% as P_2O_5), and potassium (about 6% as K_2O) are present but insufficient to support optimal biomass accumulation.

The lack of effect is probably due to an imbalance of nutrients within the vinasse formulation. Adequate nutrient uptake by roots is crucial for increasing fresh plant weight, as fresh weight primarily reflects the accumulation of photosynthates produced via photosynthesis in the leaves (Marta *et al*., 2023). Nitrogen availability and leaf quantity are particularly important, given nitrogen's role as a key component of cells and water storage organs such as leaves; insufficient nitrogen commonly reduces fresh weight. Additionally, potassium and phosphorus are vital for plant growth and development; deficiencies impair overall growth, disrupt translocation of photosynthetic products, reduce water use efficiency, and thereby inhibit cell expansion and water accumulation in tissues, resulting in smaller biomass and plant size (Singh *et al*., 2021; Thornburg *et al*., 2020; Yusuf *et al*., 2023). Both macro- and micronutrients are essential for optimal growth, emphasizing the need for balanced fertilizer formulations tailored to plant nutrient requirements (Atika *et al*., 2018; Alhasan & Al-Ameri, 2021; Xing *et al*., 2023).

Among the varieties, the Gada F1 showed a significantly higher fresh plant weight (62.75 g) than the Prabu variety (48.64 g). This difference is attributed to genetic factors that contribute to a more developed root system in Gada F1, facilitating more efficient water and nutrient absorption from the soil. Matatula *et al*. (2022) support this observation, noting that genetic variation among varieties leads to distinct phenotypic traits and growth characteristics, each with inherent advantages.

Table 5. Mean of fresh plant weight (g) for different concentrations and varieties

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	75.37	50.17	28.56 a
K_2 (6%)	56.90	48.77	28.66 a
K_3 (7%)	56.00	46.97	23.65 a
Mean	62.75 p	48.64 q	26.96 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

Table 6 shows that there was no significant interaction between the concentration of liquid organic fertilizer derived from vinasse and the red chili plant varieties tested. Furthermore, the application of liquid organic fertilizer at concentrations of 5%, 6%, and 7% did not produce statistically significant differences in the measured parameters. The absence of a significant effect on chili fruit weight may be attributed to the relatively low dosage of the vinasse-based liquid organic fertilizer used in this study. This aligns with the findings of *(Pangaribuan et al., 2022)*, who explained that insufficient nutrient supply often limits plant growth and development, preventing optimal performance. Regarding varietal differences, the dry weight of plants did not differ significantly between the Gada F1 and Prabu varieties. This suggests that the genetic potential of both varieties for biomass accumulation is relatively similar. Despite observed morphological or vegetative differences, these variations did not translate into significant differences in dry matter accumulation. (Hosseini *et al*., 2021) noted that such genetic differences are reflected in distinct phenotypic traits and growth characteristics, with each variety exhibiting its own strengths.

In Table 7, no interaction was observed between the treatment of liquid organic fertilizer concentration derived from vinasse and the variety. The application of liquid organic fertilizer at concentrations of 5%, 6%, and 7% did not produce a significant difference.

Table 6. Mean of dry weight (g) for different concentrations and varieties

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	21,6	18,02	19,83 a
K_2 (6%)	17,05	16,02	16,53 a
K_3 (7%)	19,32	18,3	18,81 a
Mean	19,34 p	17,45 p	18,39 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

This suggests that the liquid organic fertilizer does not yet satisfy the nutrient requirements of chili plants during the fruit formation phase. This is likely attributable to the limited nutrient availability in vinasse-based liquid organic fertilizer, where essential macronutrients such as nitrogen (approximately 4.5%), phosphorus (approximately 0.3% as P_2O_5), and potassium (approximately 6% as K_2O) are present but may not be sufficient to support optimal plant growth. Fruit production is expected to increase when plants receive adequate nutrients, as these nutrients facilitate growth and development during the generative phase, thereby enhancing fruit yield. Consistent with Tangahu *et al*. (2022), sufficient nutrient supply is a critical factor influencing the quality of plant growth and development, whereas nutrient deficiencies lead to stunted or suboptimal growth and yield. Additionally, the results revealed no significant difference in fruit number between varieties, likely due to

Table 7. Mean of number of fruit and fresh weight of fruit (g) for different concentrations and varieties

Consentration	Number of fruit	Fresh weight of fruit
K_1 (5%)	3.08 a	17.41 a
K_2 (6%)	2.83 a	16.30 a
K_3 (7%)	2.66 a	15.14 a
Varieties		
V_1 (Gada F1)	3.05 p	17.64 p
V_2 (Prabu)	2.66 p	14.92 q
	(-)	(-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

Table 8 demonstrates that there is no interaction between the concentration of liquid organic fertilizer derived from vinasse and the different chili varieties. Application of liquid organic fertilizer at concentrations of 5%, 6%, and 7% did not produce a significant effect. The absence of a significant effect of vinasse-based liquid organic fertilizer on chili fruit weight may be attributed to the low nutrient content of the fertilizer. The fresh weight of red chili fruit is predominantly determined by the nutrient balance received by the plant. When the nutrient composition supplied through vinasse is imbalanced, plants do not obtain adequate nutrition and thus cannot significantly increase fruit weight.

According to Topan *et al*. (2017), sufficient nutrient availability during growth facilitates plant metabolism, enhancing processes such as elongation, division, and cell differentiation, which in turn increase fruit size. Furthermore, Setiyawan *et al*. (2024) reported that major nutrients nitrogen, phosphorus, and potassium play critical roles during the generative phase of plants. Nitrogen is essential for synthesizing carbohydrates, proteins, fats, and various organic compounds. Phosphorus significantly contributes to the formation of reproductive organs, including flowers and fruits. Potassium supports multiple physiological processes, such as enzyme activation, photosynthesis, and water regulation in plants. The synergistic action of these macronutrients maximizes plant growth and yield.

The Gaada F1 variety exhibited a higher fresh fruit weight, measuring 17.64 g, which was significantly greater than that of the Prabu variety, at 14.92 g. In this study, variation in fruit weight among plants was influenced by genetic factors, as each variety possesses distinct characteristics. Pesireron *et al.* (2020) noted that differences in plant growth can result from genetic variability and the differing capacities of plants to adapt to their environmental conditions.

Table 8. Mean of fresh weight of fruit (g) for different concentrations and varieties

Concentration	Variety		Mean
	V_1 (Gada F1)	V_2 (Prabu)	
K_1 (5%)	19.01	15.80	17.41 a
K_2 (6%)	17.22	15.39	16.30 a
K_3 (7%)	16.70	13.57	15.14 a
Mean	17.64 p	14.92 q	16.28 (-)

Note : (-) = not interaction; the number followed by the same letter on the same row or column has no significant difference based on DMRT test with significant with α 5% (n = 3)

CONCLUSION

The results of the study indicate that there is no interaction between the treatments combining liquid organic fertilizer derived from vinasse and red chili varieties. Application of liquid organic fertilizer at concentrations of 5%, 6%, and 7% did not significantly affect growth and yield variables. Regarding varietal differences, the Gada F1 variety exhibited significantly higher values than the Prabu variety for the number of branches, fresh plant weight, and fresh fruit weight. The limited efficacy of vinasse-based liquid organic fertilizer at the tested concentrations may be attributed to nutrient imbalances or low bioavailability of essential elements such as nitrogen, potassium, and phosphorus. Consequently, to optimize growth and yield, it is recommended that future research investigate higher concentrations of vinasse-based liquid organic fertilizer. Increased concentrations may provide a more sufficient nutrient supply to satisfy the physiological requirements of chili plants.

References

Agustina, S., Widodo, P. & Hidayah, H. A. (2014). Analisis fenetik kultivar cabai besar (*Capsicum annuum* L.) dan cabai kecil (*Capsicum frutescens* L.). *Scripta Biologica,* 1 (1), 117–125.

Alhasan, A. S. & Al-Ameri, T. (2021). Effects of macronutrient fertilization on plant growth, essential oil content, and chemical composition in medicinal and aromatic plants grown under different environmental conditions: A review. *Volatiles & Essential Oils,* 8(6),2588–2601.

Alsebaeai, M., Chauchan, A. K., Arvind & Yadav, P. (2020). Consumption of green chili and its nutritious effect on human health. In *Innovations in food technology: Current perspectives and future goals*. Springer. DOI: https://doi.org/10.1007/978-981-15-6121-4

Arrodli, M. Z., Muhartini & Taryono. (2011). Pemanfaatan vinasse Limbah industri alkohol untuk perbaikan sifat fisik tanah dalam pengembangan tebu (*Saccharum officinarum* L.) di lahan pasir pantai. *Jurnal Sains dan Teknologi Lingkungan,* 3(2), 108–114.

Aryawati, S. A. N., Sunanjaya, I. W., Yasa, I. M. R., Kamandalu, A. A. N. B., Sari, A. R. K. & Hoerudin. (2021). Growth and productivity responses to the utilization of superior rice varieties and bio-silica application in rainfed land. *IOP Conference Series: Earth and Environmental Science,* 653(1). DOI: https://doi.org/10.1088/1755-1315/653/1/012138.

Atika, D., Silawibawa, I. P. & Sutriono, R. (2018). Pengaruh pemberian pupuk kandang mikoriza dan bio-extrim terhadap pertumbuhan dan hasil tanaman kacang tanah (*Arachis hypogaea* L.) di Kecamatan Kediri Lombok Barat. Fakultas Pertanian, Universitas Mataram.

Badan Pusat Statistik. (2024). *Rata-rata konsumsi perkapita seminggu menurut kelompok sayur-sayuran per kabupaten/kota (Satuan komoditas), 2024*.

Carrilho, E. N. V. M. & Soares, M. R. (2024). Vinasse, a byproduct of the bioethanol industry a valuable resource for sustainable agriculture and renewable energy production. In *Environmental materials and waste: Circular economy and pollution abatement* (pp. 193–239). DOI: https://doi.org/10.1016/B978-0-443-22069-2.00008-5.

Chrysargyris, A. & Tzortzakis, N. (2025). Optimizing nitrogen, phosphorus, and potassium requirements to improve *Origanum dubium* Boiss. growth, nutrient and water use efficiency, essential oil yield and composition. *Industrial Crops and Products,* 224. DOI: https://doi.org/10.1016/j.indcrop.2024.120291.

da Silva, J. J., da Silva, B. F., Stradiotto, N. R., Petrović, M., Gros, M. & Gago-Ferrero, P. (2021). Identification of organic contaminants in vinasse and in soil and groundwater from fertigated sugarcane crop areas using target and suspect screening strategies. *Science of the Total Environment,* 761. DOI: https://doi.org/10.1016/j.scitotenv.2020.143237.

Friedrichsen, C. N., Hagen-Zakarison, S., Friesen, M. L., McFarland, C. R., Tao, H. & Wulfhorst, J. D. (2021). Soil health and well-being: Redefining soil health based upon a plurality of values. *Soil Security,* 2. DOI: https://doi.org/10.1016/j.soisec.2021.100004.

Garbowski, T., Bar-Michalczyk, D., Charazińska, S., Grabowska-Polanowska, B., Kowalczyk, A. & Lochyński, P. (2023). An overview of natural soil amendments in agriculture. In *Soil and Tillage Research,* 225. DOI: https://doi.org/10.1016/j.still.2022.105462.

Hasanuzzaman, M., Bhuyan, M. H. M. B., Nahar, K., Hossain, M. S., Al Mahmud, J., Hossen, M. S., … Fujita, M. (2018). Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. *Agronomy,* 8(3), 29. DOI: https://doi.org/10.3390/agronomy8030031.

Hosseini, H., Mozafari, V., Roosta, H. R., Shirani, H., van de Vlasakker, P. C. H. & Farhangi, M. (2021). Nutrient use in vertical farming: Optimal electrical conductivity of nutrient solution for growth of lettuce and basil in hydroponic cultivation. *Horticulturae,* 7(9).

Hossain, Z., von Fragstein und Niemsdorff, P. & Heß, J. (2016). Plant origin wastes as soil conditioner and organic fertilizer: A review. *Journal of Agricultural, Food, and Environmental Sciences,* 16(7), 1362–1371.

Jia, Y., Hu, Z., Ba, Y. & Qi, W. (2021). Application of biochar-coated urea controlled loss of fertilizer nitrogen and increased nitrogen use efficiency. *Chemical and Biological Technologies in Agriculture,* 8(1). DOI: https://doi.org/10.1186/s40538-020-00205-4.

Lourenço, K. S., Costa, O. Y. de A., Cantarella, H. & Kuramae, E. E. (2022). Ammonia-oxidizing bacteria and fungal denitrifier diversity are associated with N_2O production in tropical soils. *Soil Biology and Biochemistry,* 166. DOI: https://doi.org/10.1016/j.soilbio.2022.108563..

Luo, Y., van Veelen, H. P. J., Chen, S., Sechi, V., ter Heijne, A., Veeken, A., … Bezemer, T. M. (2022). Effects of sterilization and maturity of compost on soil bacterial and fungal com munities and wheat growth. *Geoderma,* 409.

Lynch, J. P. (2011). Root phenes for enhanced soil exploration and phosphorus acquisition: Tools for future crops. *Plant Physiology,* 156(3), 1041–1049. DOI: https://doi.org/10.1104/pp.111.175414.

Marta, A., Ibnusina, F. & Zudri, F. (2023). Kajian formulasi nutrisi terhadap produksi pakcoy (*Brassica rapa* L.) pada budidaya hidroponik. *Jurnal Agrovital,* 8(1), 48–54.

Matatula, B. A., Hasanah, Y. & Charloq**.** (2022). Response of liquid organic fertilizer application to growth and yield of two *Kenikir* plant varieties (*Cosmos caudatus* Kunth.). *Jurnal Online Agroteknologi,* 10(3), 19–23. DOI:https://doi.org/10.32734/joa.v10i3.9273.

Nathaniel, O., Sam, A. R. M., Lim, N. H. A. S., Adebisi, O. & Abdulkareem, M. (2020). Biogenic approach for concrete durability and sustainabilityusinge ffective microorganisms: A review. In *Construction and Building Materials,* 261. Elsevier Ltd. DOI: https://doi.org/10.1016/j.conbuildmat.2020.119664.

Pangaribuan, N., Hidayat, C. & Rachmawati, Y**.** S. (2022). Perbaikan fisik tanah pasca galian batuan dan pertumbuhan cabai rawit dengan pemberian bahan organik dan mikroorganisme tanah. *Jurnal AGRO,* 8(1), 26–36. DOI: https://doi.org/10. 15575/17966.

Pesireron, M., Kaihatu, S. S. & Senewe, R. E. (2020). Keragaan varietas kubis (*Brassica oleracea* L.) dataran rendah dengan aplikasi mulsa di Maluku. *Jurnal Budidaya Pertanian,* 16(1), 42–50. DOI: https://doi.org/10.30598/jbdp.2020.16.1.42.

Raghothama, K. G. (1999). Phosphate acquisition. *Annual Review of Plant Physiology and Plant Molecular Biology,* 50, 665–693. http://dx.doi.org/10.1007/s11104-004-2005-6.

Rohcahyani, F. E., Hidayat, R. & Kusumaningrum, N. A. (2025). Sustainable fertilization strategy: The effect of mono potassium phosphate and amino acid liquid organic fertilizer on melon plants. *Agro Bali: Agricultural Journal,* 8(2), 525–537. DOI: https://doi.org/10.37637/ab.v8i2.2075.

Samputri, H. A., Guniarti, G. & P. S., R. D. (2023). Pengaruh dosis POC kulit pisang dan guano terhadap pertumbuhan terong ungu (*Solanum melongena* L.). *Agro Bali: Agricultural Journal,* 6(2), 413–420. DOI: https://doi.org/10.37637/ab.v6i2.1172.

Sardans, J. & Peñuelas, J. (2021). Potassium control of plant functions: Ecological and agricultural implications. *Plants,* 10(2), Article 419. DOI: https://doi.org/10.3390/plants10020419.

Scull, I., Savón, L., Gutiérrez, O., … Noda, A**.** (2012). Physic-chemical composition of concentrated vinasse for their assessment in animal diets. *Cuban Journal of Agricultural Science,* 46(4), 385–389.

Setiyawan, A., Octavia, D., Maryati, Y., Widata, S., Pamungkas, D. H. & Khairi, A. (2024). Adaptation test of rice varieties (*Oryza sativa* L. var. Inpari) with various doses of NPK fertilizer in rice field. *TERRA: Journal of Land Restoration,* 7(2), 103–109. DOI: https://doi.org/10.31186/terra.7.2.103-109.

Shah, I. H., Jinhui, W., Li, X., … Chang, L. (2024). Exploring the role of nitrogen and potassium in photosynthesis: Implications for sugar accumulation and translocation in horticultural crops. In *Scientia Horticulturae*, 327. DOI: https://doi.org/10.1016/j.scienta.2023.112832.

Shrivastaav, P., Prasad, M., Singh, T. B., … Dantu, P. K. (2020). Role of nutrients in plant growth and development. In *Contaminants in agriculture: Sources, impacts and management*. Springer International Publishing. DOI: https://doi.org/10.1007/978-3-030-41552-5.

Singh, V. K., Dwivedi, B. S., Rathore, S. S., … Majumdar, K. (2021). Timming potassium application to synchronize with plant demand. In T. S. Murell et al. (Eds.), *Improving potassium recommendations for agricultural crops*. Springer Nature.

Sinha, D. & Tandon, P. K. (2020). An overview of nitrogen, phosphorus and potassium: Key players of nutrition process in plants. In *Sustainable solutions for elemental deficiency and excess in crop plants* (pp. 85–117). Springer Singapore. DOI: https://doi.org/10.1007/978-981-15-8636-1_5.

Suhastyo, A. A. (2019). Pemberdayaan kelompok wanita tani melalui pelatihan pembuatan pupuk organik cair. *Jurnal PPKM,* 6(2), 60–64.

Tangahu, I., Arief Azis, M. & Jamin, F. S. (2022). Respon pertumbuhan dan produksi tanaman cabai (*Capsicum annuum* L.). *Jurnal Agroteknotropika,* 11(1), 10–17.

Tariq, A., Zeng, F., Graciano, C., … Zhang, Z. (2023). Regulation of metabolite by nutrients in plants. In V. P. Singh & M. H. Siddiqui (Eds.), *Plant ionomics: Sensing, signaling, and regulation* (pp. 1–18).

Thornburg, T. E., Liu, J., Li, Q., … Pan, X. (2020). Potassium deficiency significantly affected plant growth and development as well as microRNA-mediated mechanism in wheat (*Triticum aestivum* L.). *Frontiers in Plant Science,* 11. DOI: https://doi.org/10.3389/fpls.2020.01219.

Topan, N., Yetti, H., Ali, M. (2017). Pengaruh dosis limbah cair biogas ternak terhadap pertumbuhan dan hasil tanaman cabai (*Capsicum annuum* L.) di Tanah Podzolik Merah Kuning. *JOM Faperta,* 4(1), 1–12.

Vance, C. P., Uhde-Stone, C. & Allan, D. L. (2003). Phosphorus acquisition and use: Critical adaptations by plants for securing a nonrenewable resource. *New Phytologist,* 157 (3), 423–447. DOI: https://doi.org/10.1046/j.1469-8137.2003.00695.x.

Verma, B. C., Pramanik, P. & Bhaduri, D. (2019). Organic fertilizers for sustainable soil and environmental management. In *Nutrient dynamics for sustainable crop production*. Springer Singapore. DOI: https://doi.org/10.1007/978-981-13-8660-2.

Wibowo, A. S. (2021). Interaksi dosis air cucian beras dan jenis media tanam terhadap pertumbuhan awal tanaman terong (*Solanum melongena* L.). *Journal Grafting,* 11(1), 10–16.

Wulandari, Y., Respatie, D. W. & Alam, T. (2023). Pengaruh kombinasi pupuk N-P-K dan vinasse diperkaya mikroba terhadap pertumbuhan dan hasil kedelai (*Glycine max* L. Merrill). *Vegetalika,* 12(3), 198. DOI: https://doi.org/10.22146/veg.78636.

Xing, G., Ma, J., Liu, X., … Han, Y. (2023). Influence of different nitrogen, phosphorus, and potassium fertilizer ratios on the agronomic and quality traits of foxtail millet. *Agronomy,* 13(8). DOI: https://doi.org/10.3390/agronomy13082005.

Yan, T., Xue, J., Zhou, Z. & Wu, Y. (2021). Biochar-based fertilizer amendments improve the soil

microbial community structure in a karst mountainous area. *Science of the Total Environment,* 794. DOI: https://doi.org/10.1016/j.scitotenv.2021.148757.

Yulina, N., Ezward, C., Haitami, A. & Kuantan Singingi, I. (2021). Karakter tinggi tanaman, umur panen, jumlah anakan dan bobot panen pada 14 genotipe padi lokal. *Jurnal Agrosains dan Teknologi,* 6(1), 15–24.

Yusuf, M., Fitria, F., Risnawati, R., … Alridiwirsah, A. (2023). Application of potassium fertilizer and organic fertilizer for rabbits on the growth and years of okra (*Abelmoschus esculentus* L.). *Jurnal Agronomi Tanaman Tropika,* 5(1), 185–192. DOI: https://doi.org/10.36378/juatika.v5i1.2716.

Zhang, Y., Tao, W., Zhu, K., … Yang, J. (2024). Coated and uncoated urea incorporated with organic fertilizer improves rice nitrogen uptake and mitigates gaseous active nitrogen loss and microplastic pollution. *Agriculture, Ecosystems and Environment,* 375. DOI: https://doi.org/10.1016/j.agee.2024.109201.

Zi, J., Liu, T., Zhang, W., … Zhu, H. (2024). Quantitatively characterizing sandy soil structure altered by MICP using multi-level thresholding segmentation algorithm. *Journal of Rock Mechanics and Geotechnical Engineering,* 16(10), 4285–4299. DOI: https://doi.org/10.1016/j.jrmge.2023.11.025.

Zikeli, S., Deil, L. & Möller, K. (2017). The challenge of imbalanced nutrient flows in organic farming systems: A study of organic greenhouses in Southern Germany. *Agriculture, Ecosystems and Environment,* 244, 1–13. DOI: https://doi.org/10.1016/j.agee.2017.04.017.