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The impact of applying liquid organic fertilizer and inorganic fertilizer on the growth and yield of curly red chili in dryland

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ABSTRACT

Curly red chilies (*Capsicum annum* L.) are one of the vegetable commodities that are widely cultivated by Indonesian farmers because they have high economic value and have several health benefits. This research aims to determine the effect of applying liquid organic fertilizer (LOF) at various concentrations and doses of inorganic fertilizer on the growth and yield of curly chili. The research was conducted at Gumantar Village, Kayangan District, North Lombok Regency, West Nusa Tenggara Province, Indonesia, at an altitude of 60 m asl starting from April to July 2018. This research used a Completely Randomized Block Design consisting of two factors. The first factor is the application of the LOF concentration and the second factor is the application of the inorganic fertilizer dose. The research results showed that the application of LOF combined with inorganic fertilizer did not significantly differ in stem diameter, number of branch/plant, and total of fruit weight/plant, but it was significantly different from the height of the plant at 42 DAP (maximum vegetative phase). The observed curly chilli fruit did not produce significantly different values with various treatment combinations. However, sole fertilizer in LOF is very responsive at the beginning of growth (14 DAP) which can be seen in height plants.

Keywords: Curly Chili, Inorganic Fertilizer, Organic Farming, Organic Fertilizer

ABSTRAK

Cabai merah keriting (Capsicum annum L.) merupakan salah satu komoditas sayuran yang banyak dibudidayakan oleh petani Indonesia karena memiliki nilai ekonomi yang tinggi dan memiliki beberapa manfaat kesehatan. Penelitian ini bertujuan untuk mengetahui pengaruh pemberian pupuk organik cair (POC) pada berbagai konsentrasi dan dosis pupuk anorganik terhadap pertumbuhan dan hasil tanaman cabai keriting. Penelitian telah dilakukan di Desa Gumantar, Kecamatan Kayangan, Kabupaten Lombok Utara, Provinsi Nusa Tenggara Barat, Indonesia pada ketinggian 60 m dpl yang dimulai dari bulan April sampai dengan Juli 2018. Penelitian ini

menggunakan Rancangan Acak Kelompok Lengkap yang terdiri dari dua faktor. Faktor pertama adalah penerapan konsentrasi POC dan faktor kedua adalah penerapan dosis pupuk anorganik. Hasil penelitian menunjukkan bahwa pemberian POC yang dikombinasikan dengan pupuk anorganik tidak memberikan perbedaan nyata pada diameter batang, jumlah cabang/tanaman, dan total berat buah/tanaman, namun berbeda nyata dengan tinggi tanaman pada umur 42 HST (fase vegetatif maksimum). Buah cabai keriting yang diamati tidak menghasilkan nilai berbeda nyata dengan berbagai kombinasi perlakuan. Namun pupuk tunggal pada POC sangat responsif pada awal pertumbuhan (14 HST) yang terlihat pada tinggi tanaman.
Kata kunci; *Cabai Keriting, Pertanian Organik, Pupuk Anorganik, Pupuk Organik*

1. INTRODUCTION

Curly red chilies (*Capsicum annum* L.) are a type of chili plant that is long and slender but has a curly texture. Curly chilies are usually red, but there are also curly chilies that are green. It tastes spicy, and inside there are very small but very hard seed. The seeds from curly red chilies are what produce a spicy taste when eaten. Curly red chilies contain several vitamins such as C, B1, B2, calcium (Ca), phosphorus (P), and alkaline compounds such as capsaicin which are quite high when compared to other vegetables (Alsebaeai et al., 2020).

According to the Central Statistics Agency (BPS) and the Directorate General of Horticulture-Ministry of Agriculture (2021), the productivity of chili in Indonesia from 2017 to 2020 increased by 8.46, 8.77, 9.10, and 9.43 ton/ha. One way to increase the production of chilies while at the same time addressing the high demand from the public is with fertilizer management, which is part of agricultural intensification (Fonte et al., 2012). Fertilization is an action that aims to add nutrients that are already in the soil, provide nutrients that are not yet available in the soil, and replace nutrients transported by plants through harvest. (Paungfoo-Lonhienne et al., 2012; Timsina, 2018).

The use of organic fertilizer more specifically provides benefits, namely improving soil structure as a source of nutrients for plants, increasing soil humus content, increasing the activity of microorganisms, increasing water holding capacity, reducing erosion and leaching of dissolved nitrogen, increasing cation exchange capacity in soil (Verma, 2020). The effect of using organic fertilizer is that it can increase buffering capacity against changes in soil properties, increasing the work of soil microbes in the process of decomposition of organic material. Khan (2018) added that organic fertilizer will form complex compounds with metal ions that are poisonous to plants such as Al, Fe, and Mn.

Organic fertilizer is dominantly in solid or granular form, but with advanced technology organic fertilizer can be found in liquid form. One of the liquid organic fertilizer (LOF) products is Bio-Extrim fertilizer. It contains microbes and nutrients that can increase plant production and break down nutrients in the soil (Lubis et al., 2019). The types of microbes contained in organic fertilizer are Azospirillum sp.,

Azotobacter sp., Rhizobium sp., Pseudomonas sp., Bacillus sp., and phosphate solubilizing bacteria (Thomas & Singh, 2019; Kour et al., 2020).

Bio-Extrim was studied by Khairi et al. (2023) on tomato (*Solanum lycopersicum* L.) in dryland. Furthermore, the study conducted by Apriza (2018) states that organic fertilizer can provide nutrients in a form that is available and can be absorbed by plants to stimulate physiological processes in plant growth. Based on the results of this research, research was conducted on the effect of providing liquid organic fertilizer and inorganic fertilizer on the growth and yield of curly red chili.

2. MATERIALS AND METHOD

This research began in April to July 2018 at Gumantar Village, Kayangan District, North Lombok Regency, West Nusa Tenggara Province, Indonesia, at an altitude of 60 m asl (Figure 1). This research used a Randomized Complete Block Design (RCBD) consisting of two factors. The first factor is the application of liquid organic fertilizer (the brand Bio-Extrim) with concentration, which consists of three levels: B1 = 5.30 mL/L, B2 = 6.70 mL/L, and B3 = 9.30 mL/L. The second factor is the application of inorganic fertilizer (the brand of NPK Mutiara) with doses, which consist of three levels: N1= 0 g/plant (control), N2 = 1.20 g/plant, and N3 = 2.40 g/plant. Therefore, there were nine treatment combinations and three replications to obtain 27 experimental units. Basic fertilization is the application of organic fertilizer (the brand of Pupuk Organik Petroganik) at 1 ton/ha at the same time as soil processing. Plants were applied LOF treatment at 14, 28, and 42 days after planting (DAP). Meanwhile, inorganic fertilizer is applied at 16, 30, and 44 DAP. The seeds of curly red chili var. Berco F1 (the brand of TMjawarabibit) and water were given once a week by irrigation and depending on rain. The planting distance was 60 × 40 cm. Planting in the experimental field was carried out when plants were 21 days after seedling (DAS). Control of pests and plant diseases with chemicals with a concentration of 1,000 ppm. The fungicide used was Amistar Top and the insecticide used was Voliam Targo. Plants are harvested at the age of 3 months after seedling with a harvesting process once every 1 week, or harvesting was performed in the 1st week of harvest (70–76 DAP) to the 5th week (94–100 DAP). The criteria for fruit that is ready to harvest is that the color of the fruit is red from green.

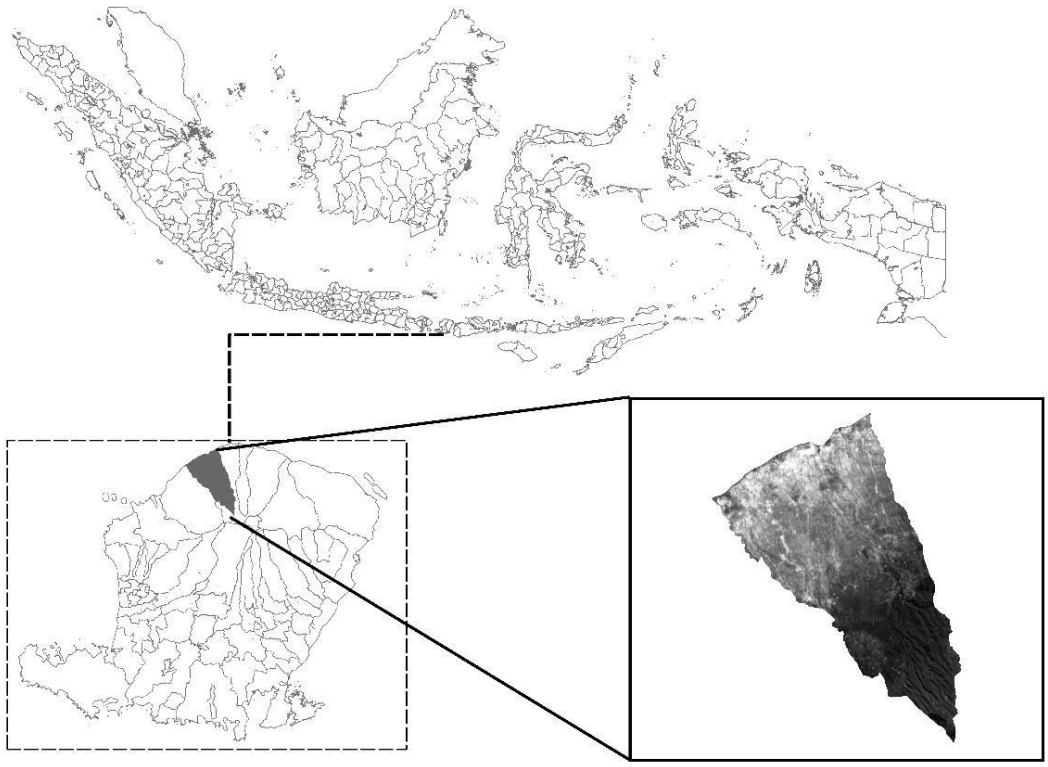

Figure 1. GPS coordinates of the experimental site (latitude 8°14'59"S and longitude 116°17'30"E)

The variables observed in this research were height of plant, stem diameter, number of branch/plant, and total of fruit weight/plant. The observation data were analyzed using Analysis of Variance (ANOVA) 5%. The result of the ANOVA, which showed a significant difference, was tested with post-hoc analysis using Tukey's Honest Significant Difference (HSD) of 5%. Software used for data analysis and Pearson's correlation was SAS® OnDemand for Academics via a web browser (https://welcome.oda.sas.com/login) and Minitab v.21.4.1. Pearson's correlation coefficient scale includes 0.00–0.19 = very low, 0.20–0.39 = low, 0.40–0.59 = medium, 0.60–0.79 = high, and 0.80–1.00 = very high (Utari et al., 2023).

3. RESULTS AND DISCUSSION

Chili can be divided into three types, namely large chili, cayenne pepper, and curly chili (Syukur et al., 2022). Curly chili is a type of chili that belongs to the large chili group with the main characteristic of curly fruit shape (Herison et al. 2018). Zhou et al. (2019) reported that consumption of spicy food can increase human brain activity. Capsaicin is the main biochemical content in chili fruit, which produces the

spiciness (Lu et al. 2020). This research tested the plant at variables of plant height, stem diameter, number of branch/plant and total of fruit weight/plant. The data on plant height is displayed in Table 1.

Table 1. Height of plant of curly red chili with various types of fertilizer

Treatments	Height Plant (cm)						
	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP	56 DAP
Liquid Organic Fertilizer (B)							
5.30 mL/L	24.29 a	34.23 a	47.69 a	57.76 a	67.88 a	84.08 a	95.53 a
6.70 mL/L	23.12 ab	32.99 a	46.19 a	56.79 a	69.42 a	84.46 a	95.84 a
9.30 mL/L	21.73 b	31.83 a	45.80 a	57.30 a	72.16 a	86.36 a	93.60 a
Inorganic Fertilizer (N)							
0 g/plant	23.08 a	33.48 a	46.08 a	56.24 a	69.43 ab	87.11 a	96.40 a
1.20 g/plant	23.04 a	32.73 a	47.18 a	58.50 a	74.48 a	86.44 a	97.49 a
2.4 g/plant	23.02 a	32.84 a	46.42 a	57.14 a	65.54 b	81.33 a	91.09 a
B	S	NS	NS	NS	NS	NS	NS
N	NS	NS	NS	NS	S	NS	NS
Interaction B x N (+/-)	-	-	-	-	+	-	-

Note: The number followed by the same letter in column and treatments factor of same has no significant difference based on Tukey's HSD test 5%; S = significant; NS = non-significant; (+) = interaction; (-) = not interaction

A height plant is a measure of plants that is often observed both as an indicator of growth and as a variable used to measure the influence of the environment or the treatment applied (Moles et al., 2009). Based on Table 1, the effects of combination fertilizer treatments both had significantly different effects at the age of 42 DAP but were not significantly different at the age of 14-35 DAP and the age of 49-56 DAP. The data in Table 1 shows that the average results of height plant with the LOF treatment obtained in treatment B1 were higher compared to other treatments at 14 DAP. In the B1, the macronutrient requirements for N, P, and K were able to be absorbed. Nitrogen is needed to form important compounds of nucleic acids, enzymes, proteins, and chlorophyll, especially for vegetative plant growth (Ohyama, 2010; Anas et al., 2020; Shrivastav et al., 2020). Potassium plays a role in the formation of starch, activates enzymes, helps physiological and metabolic processes in cells, and increases resistance to drought and disease (Oosterhuis et al., 2014; Hasanuzzaman et al., 2018; Sardans & Peñuelas, 2021). If the available nitrogen and phosphorus elements are low, the plant will grow slowly and become stunted (Hardjowigeno, 1995; Sinha & Tandon, 2020). In the B3 treatments, there was a decrease in height plant. This was caused by the higher levels of fertilizer given, which would cause a decrease in soil fertility and productivity, which would affect plant growth. According to Atika (2018), macro and micronutrients greatly influence plant growth. Therefore, fertilizer must be balanced according to plant needs.

Table 2. Stem diameter of curly red chili with various types of fertilizer

Treatments	Stem Diameter (cm)						
	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP	56 DAP
Liquid Organic Fertilizer (B)							
5.30 mL/L	1.33 a	1.56 a	1.74 a	1.93 a	2.10 a	2.32 a	2.52 a
6.70 mL/L	1.33 a	1.54 a	1.74 a	1.91 a	2.06 a	2.32 a	2.50 a
9.30 mL/L	1.33 a	1.54 a	1.73 a	1.92 a	2.12 a	2.34 a	2.58 a
Inorganic Fertilizer (N)							
0 g/plant	1.32 a	1.56 a	1.74 a	1.90 a	2.08 a	2.32 a	2.52 a
1.20 g/plant	1.33 a	1.54 a	1.73 a	1.92 a	2.10 a	2.33 a	2.53 a
2.4 g/plant	1.34 a	1.54 a	1.74 a	1.94 a	2.10 a	2.33 a	2.54 a
B	NS	NS	NS	NS	NS	NS	NS
N	NS	NS	NS	NS	NS	NS	NS
Interaction B x N (+/-)	-	-	-	-	-	-	-

Note: The number followed by the same letter in column and treatments factor of same has no significant difference based on Tukey's HSD test 5%; S = significant; NS = non-significant; (+) = interaction; (-) = not interaction

Based on the results of the variance analysis, the stem diameter showed that it was not significantly different in all treatments, regardless of the age of the plant (Table 2). This is because the effect between fertilizer concentrations/doses does not produce significantly different values. The concentrations/doses must be given at a higher value to increase the stem diameter of curly red chili.

Table 3. Number of branch/plant and total of fruit weight/plant of curly red chili with various types of fertilizer

Treatments	Number of Branch/Plant	Total of Fruit Weight/Plant (g)
Liquid Organic Fertilizer (B)		
5.30 mL/L	2.03 a	113.38 a
6.70 mL/L	2.17 a	107.59 a
9.30 mL/L	2.04 a	115.97 a
Inorganic Fertilizer (N):		
0 g/plant	2.09 a	113.88 a
1.20 g/plant	2.08 a	110.76 a
2.4 g/plant	2.08 a	112.30 a
B	NS	NS
N	NS	NS
Interaction B x N (+/-)	-	-

Note: The number followed by the same letter in column and treatments factor of same has no significant difference based on Tukey's HSD test 5%; S = significant; NS = non-significant; (+) = interaction; (-) = not interaction

Based on the results of the number of branch/plant and total of fruit weight/plant, the effects of all treatments showed that the effects were not significantly different (Table 3). This is because the effect between fertilizer concentrations/doses does not produce significantly different values. The concentrations/doses must be given at a higher value to increase and support maximum vegetative growth and yield. As research reported by Adirianto et al. (2022) is able to produce effective fertilizer applications. His research reported that the application of biological fertilizer can increase fruit weight of curly red chili compared to non-treatment (control).

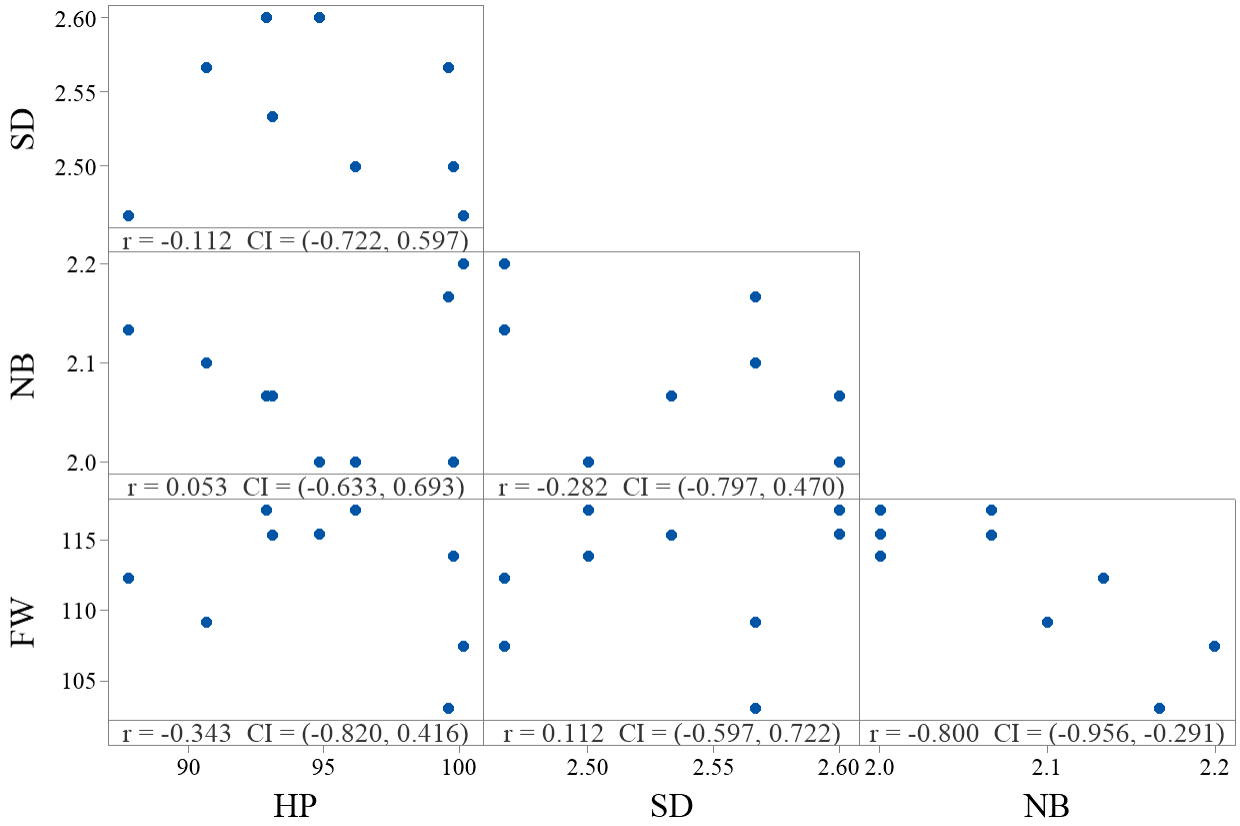

Figure 2. Pearson's correlation on observation variable with HP = height plant; SD = stem diameter; NB = number of branch/plant; FW = total of fruit weight/plant

Pearson's correlation is a form of formula used to find the relationship between two variables, namely the independent variable and the dependent variable. According to Utari et al. (2023), the value

obtained after the analysis was classified as very low (<0.19). This data from Figure 2 has a value that shows a very low linear relationship between the two variables.

4. CONCLUSION

The application of LOF combined with inorganic fertilizer did not significantly differ in stem diameter, number of branch/plant, and total of fruit weight/plant, but it was significantly different from height plant at 42 DAP. LOF and inorganic fertilizer will produce the best performance and respond to the maximum vegetative phase (42 DAP) in curly red chilies in dryland, and it also has a significant effect on inorganic fertilizer. The observed curly red chili fruit did not produce significantly different values with various treatment combinations. However, sole fertilizer in LOF is very responsive at the beginning of growth (14 DAP) which can be seen in height plant.

5. REFERENCES

Adirianto, B., Krisnawati, E., Sulistyowati, D. & Utami, A D. (2022). Combination of of biological fertilizers and inorganic fertilizers to increase productivity of red curly chili (*Capsicum annuum* L.). Tropical Plantation Journal. 1(1), 1–6. https://doi.org/10.22013/tpj.v1I1.1

Alsebaeai, M., Chauhan, A.K., Arvind, Yadav, P. (2020). Consumption of Green Chilli and Its Nutritious Effect on Human Health. In: Mishra, P., Mishra, R.R., Adetunji, C.O. (eds) Innovations in Food Technology. Springer, Singapore. https://doi.org/10.1007/978-981-15-6121-4_26

Anas, M., Liao, F., Verma, K. K., Sarwar, M. A., Mahmood, A., Chen, Z. L., ... & Li, Y. R. (2020). Fate of nitrogen in agriculture and environment: agronomic, eco-physiological and molecular approaches to improve nitrogen use efficiency. Biological Research, 53(1), 1–20. https://doi.org/10.1186/s40659-020-00312-4

Apriza, Alvina Deva. (2018). Pengaruh Pemberian Pupuk NPK, Pupuk Kompos Krinyuh (*Chromolaena odorata* L.) dan Pupuk Bio-Extrim Terhadap Pertumbuhan dan Hasil Tanaman Cabai Merah. Fakultas Pertanian. Universitas Mataram.

Atika, Dewi. (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 [BPS]. (2021). Produksi, luas lahan dan produktivitas tanaman cabai di Indonesia. https://www.bps.go.id/id/publication/2021/02/26/938316574c78772f27e9b477/statistik-indonesia-2021.html. [January 10, 2024].

Fonte, S. J., Vanek, S. J., Oyarzun, P., Parsa, S., Quintero, D. C., Rao, I. M., & Lavelle, P. (2012). Pathways to agroecological intensification of soil fertility management by smallholder farmers in the Andean highlands. Advances in Agronomy, 116, 125–184. https://doi.org/10.1016/B978-0-12-394277-7.00004-X

Hardjowigeno, S. 1995. Ilmu Tanah. Akademika Pressindo, Jakarta.

Hasanuzzaman, M., Bhuyan, M. B., Nahar, K., Hossain, M. S., Mahmud, J. A., Hossen, M. S., ... & Fujita, M. (2018). Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. Agronomy, 8(3), 31. https://doi.org/10.3390/agronomy8030031

Herison, C., Surmaini, E., Rustikawati, & Yulian. (2018). Morphological characterization of 10 hot pepper genotipes in low altitude location. Akta Agrosia. 21(2), 47–54. https://doi.org/10.31186/aa.21.2.47-54

Khairi, A., Jayaputra, Padusung, Tejowulan, S., & Nurrachman. (2023). Combination of bio-organo-mineral fertilizers on optimizing the growth and production of tomatoes (*Solanum lycopersicum* L.) in dryland environment. Jurnal Ilmiah Pertanian, 20(2), 127–138. https://doi.org/10.31849/jip.v20i2.10901

Khan, M. N., Mobin, M., Abbas, Z. K., & Alamri, S. A. (2018). Fertilizers and their contaminants in soils, surface and groundwater. Encyclopedia of the Anthropocene, 5, 225–240.

Kour, D., Rana, K. L., Yadav, A. N., Yadav, N., Kumar, M., Kumar, V., ... & Saxena, A. K. (2020). Microbial biofertilizers: Bioresources and eco-friendly technologies for agricultural and environmental sustainability. Biocatalysis and Agricultural Biotechnology, 23, 101487. https://doi.org/10.1016/j.bcab.2019.101487

Lu, M., Chen, C., Lan, Y., Xiao, J., Li, R., Huang, J., Huang, Q., Cao, Y., Ho, C. T. (2020). Capsaicin-the major bioactive ingredient of chili peppers: Bio-efficacy and delivery systems. Food & Function, 11(4), 2848–2860. https://doi.org/10.1039/D0FO00351D

Lubis, A. R., Sembiring, M., & Outhor, C. (2019). The effect of the combination of palm oil waste factory (lpks) and cattle waste (lts) in solid-liquid and liquid-solid of sweet corn plants (*Zea mays* Saccharata L). International Journal of Education and Research, 7(6), 237–246.

Moles, A. T., Warton, D. I., Warman, L., Swenson, N. G., Laffan, S. W., Zanne, A. E., ... & Leishman, M. R. (2009). Global patterns in plant height. Journal of Ecology, 97(5), 923–932. https://doi.org/10.1111/j.1365-2745.2009.01526.x

Ohyama, T. (2010). Nitrogen as a major essential element of plants. Nitrogen Assim. Plants, 37, 1-17.

Oosterhuis, D. M., Loka, D. A., Kawakami, E. M., & Pettigrew, W. T. (2014). The physiology of potassium in crop production. Advances in Agronomy, 126, 203–233. https://doi.org/10.1016/B978-0-12-800132-5.00003-1

Paungfoo-Lonhienne, C., Visser, J., Lonhienne, T. G., & Schmidt, S. (2012). Past, present and future of organic nutrients. Plant and Soil, 359, 1–18. https://doi.org/10.1007/s11104-012-1357-6

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

Shrivastav, P., Prasad, M., Singh, T. B., Yadav, A., Goyal, D., Ali, A., & Dantu, P. K. (2020). Role of Nutrients in Plant Growth and Development. In: Naeem, M., Ansari, A., Gill, S. (eds) Contaminants in Agriculture. Springer, Cham. https://doi.org/10.1007/978-3-030-41552-5_2

Sinha, D., & Tandon, P. K. (2020). An Overview of Nitrogen, Phosphorus and Potassium: Key Players of Nutrition Process in Plants. In: Mishra, K., Tandon, P.K., Srivastava, S. (eds) Sustainable Solutions for Elemental Deficiency and Excess in Crop Plants. Springer, Singapore. https://doi.org/10.1007/978-981-15-8636-1_5

Syukur, M., Sahid, Z. D., Sobir, Maharijaya, A., Ritonga, A. W., Yunandra, Sulassih, Istiqlal, M. R. A., Hakim, A., Wahyu, Y., Vicente, T. M., Mukhlisin, Agustina, K., Yursida, Muslimin, K., Hafsah, S., Nura, & Setyawan A. (2022). Yield evaluation of curly chili lines in three lowland locations. Biodiversitas. 23(6), 3219–3223. https://doi.org/10.13057/biodiv/d230649

Thomas, L., & Singh, I. (2019). Microbial Biofertilizers: Types and Applications. In: Giri, B., Prasad, R., Wu, QS., Varma, A. (eds) Biofertilizers for Sustainable Agriculture and Environment. Soil Biology, vol 55. Springer, Cham. https://doi.org/10.1007/978-3-030-18933-4_1

Timsina, J. (2018). Can organic sources of nutrients increase crop yields to meet global food demand?. Agronomy, 8(10), 214. https://doi.org/10.3390/agronomy8100214

Utari, S. R. P., Zulfa, F., Gedeon, I., Purnamasari, A., & Khairi, A. (2023). Development and potential of soybean (*Glycine max* (L.) Merrill) in Banjarnegara Regency. Jurnal Sains Agribisnis. 3(2), 92–101. https://doi.org/10.55678/jsa.v3i2.1265

Verma, B. C., Pramanik, P., & Bhaduri, D. (2020). Organic Fertilizers for Sustainable Soil and Environmental Management. In: Meena, R. (eds) Nutrient Dynamics for Sustainable Crop Production. Springer, Singapore. https://doi.org/10.1007/978-981-13-8660-2_10

Zhou, Y., Gao, X., Small, D. M., & Chen, H. (2019). Extreme spicy food cravers displayed increased brain activity in response to pictures of foods containing chili peppers: an fMRI study. Appetite. 142, 104379. https://doi.org/j.appet.2019.104379