PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (6) 1729-1736 June 2024

Application of Bokashi Organic and Nitrogen-Phosphorous-Potassium Inorganic Fertilizers on the Growth and Yield of Lettuce (*Lactuca sativa* L.) in a Hydroponic System at a Green House in Madiun, Indonesia

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ABSTRACT*:* Urban farming is a current trend because of the many benefits it can obtain economically, healthily, ecologically, and socially. Limited urban land, especially residential environments, requires practical and economical cultivation techniques, including a hydroponic system. Hence, the objective of this paper was to apply Bokashi organic and nitrogen-phosphorous-potassium (NPK) inorganic fertilizer to the growth and yield of lettuce (*Lactuca sativa* L.) in a hydroponic system at a greenhouse in Madiun, Indonesia using standard methods from December 2023 to January 2024. The study showed that using organic bokashi fertilizer with NPK inorganic fertilizer gave good results, which is no different from AB-Mix instant nutrition regarding growth and the harvested product. Organic fertilizer without additional NPK provides less than optimal growth due to a lack of macronutrients. Further, more applied research is needed to obtain a farmer-friendly hydroponic technology package that is truly applicable, easy, and cheap so that it can strengthen urban farming programs in many metropolitan areas in Indonesia.

DOI: **https://dx.doi.org/10.4314/jasem.v28i6.11**

Cite this Article as: WURYANTORO; WARDHANI, RM; MARTONO, DS; SRI RAHAYU (2024). Application of Bokashi Organic and Nitrogen-Phosphorous-Potassium Inorganic Fertilizers on the Growth and Yield of Lettuce (*Lactuca sativa* L.) in a Hydroponic System at a Green House in Madiun, Indonesia. *J. Appl. Sci. Environ. Manage.* 28 (6) 1729-1736

Dates: Received: 29 February 2024; Revised: 22 April 2024; Accepted: 28 May 2024 Published: 11 June 2024

Keywords*:* hydroponics; bokashi organic fertilizer; NPK-fertilizer; urban farming; lettuce

The United Nations Food and Agriculture Organization states that the world population will reach nine billion people by 2050, of which 75% will live in cities. In this context, the hydroponics agricultural method of growing plants using water-based nutrients rather than soil would be advantageous due to the scarcity of land in towns (Roberto, 2022). Hydroponics comes from the words "hydro," which means water, and "ponos," which means work. The concept of hydroponics dates back thousands of years, as shown by the Hanging Gardens of Babylon and the Floating Gardens in China (Niu; Masabni, 2022). Lettuce is a vegetable popular with Indonesians, with consumers ranging from the lower class to the upper class, and is used in dishes such as salads, burgers, and "gado-gado." Lettuce contains various nutrients, including dietary fiber, vitamin A, and minerals. The nutritional content of lettuce, especially vitamins and minerals, is substituted for staple foods (Romalasari; Sobari, 2019). Lettuce leaves are rich in antioxidants

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such as beta-carotene, folic acid, and lutein and contain indole, which effectively protects the body from cancer. The natural fiber content helps maintain digestive health. Lettuce contains a variety of chemicals, making it a versatile plant. Lettuce also acts as a medicine and blood purifier to treat coughs, inflammation, dermatitis, insomnia, and hemorrhoids. The nutritional content in 100 g of lettuce includes calories 15.00 cal, protein 1.20 g, fat 0.2 g, carbohydrates 2.9 g, Ca 22.00 mg, P 25 mg, Fe 0.5 mg, vitamin A 540 SI, vitamin B 0.04 mg, and water 94.80 g (Lestari, 2014). Hydroponic plant cultivation, apart from using inorganic fertilizers, can also use organic fertilizers. Continuous use of inorganic fertilizers can prevent the role of chemical fertilizers from becoming ineffective. Organic fertilizer can be one solution to reducing fertilizer use (Muhadiansyah et al., 2016). The hydroponic system has a weakness, namely that the use of nutrients only uses inorganic fertilizer, which can cause residual effects on plants. Therefore, using organic fertilizer in the hydroponic system can be an alternative to meet the nutritional needs of plants. Apart from that, organic fertilizer is an environmentally friendly fertilizer that provides continuous nutrition and plays a dual role that benefits plants (Rana et al., 2018). The results of research on tomato plants show that hydroponic nutrient solutions formulated using local organic materials can improve tomatoes' quality, growth, and reproductive performance. However, it still requires further optimization (Mowa, 2018). Hydroponic farming for ordinary people is synonymous with a complicated system with expensive costs, so it has yet to be widely practiced in the wider community. Creating a hydroponic system with a simple and cheap system is therefore very necessary, using materials available around the community. Developing low-cost, easy-to-operate techniques requiring little labor is essential, thereby successfully lowering overall setup and operational costs to implement commercial hydroponic technology (Sharma, 2018).

One organic material that can improve plant yields is bokashi, a fertilizer resulting from the fermentation of organic materials using EM-4 technology. Bokasi fertilizer can increase and improve plant growth and yield. The advantage of bokasi fertilizer is that it contains complete macronutrients and micronutrients. The nutrients include N, P, K, Ca, Mg, S, Mn, Cu, Zn, B, and Mo. Even though the nutrient elements are more minor than inorganic fertilizers, bokashi fertilizer is an alternative fertilizer whose raw materials are easily obtained in the surrounding environment (Windi *et al.,* 2022). The elements N, P, and K are the primary macro elements plants need, so they must be available in large quantities. NPK fertilizer is an artificial chemical fertilizer, an inorganic compound fertilizer that can be used very efficiently in increasing the availability of macronutrients (N, P, and K), replacing single fertilizers such as Urea, SP-36, and KCl, which are sometimes difficult to obtain on the market and very expensive. The advantage of using compound NPK fertilizer compared to a single fertilizer is that one fertilizer application can cover several elements, making it more efficient and saving time, labor, and transportation costs (Ramadhan *et al.,* 2021). Organic fertilizer, in essence, contains complete nutrients, so it has the potential for hydroponic nutrition. However, it is lacking in terms of the availability of macronutrients, especially N, P, and K. NPK fertilizer has an essential role in plant growth, including encouraging root development and early fruiting and stimulating the translocation of carbohydrates from leaves to plant organs. To obtain the most appropriate concentration measurements is necessary to study the extent of the interaction between organic fertilizer and NPK fertilizer. The results of this research will underlie much hydroponic research using various methods, creations, and technologies according to the needs and availability of financial resources, place, time, and expertise required. Vertically, this system product is expected to become input for various efforts to produce added value. Research on organic fertilizer in liquid form (POC) has been widely carried out, including as an addition to AB-Mix (Omoranda et al., 2016), as a nutrient in hydroponic wick systems (Bachtiar et al., 2021) (using the Hydroponic Floating Raft Technique (Lakshitowati *et al.,* 2021). There has not been much research on using solid organic fertilizer as hydroponic nutrition. Hence, the objective of this paper was to apply Bokashi organic and nitrogen-phosphorous-potassium (NPK) inorganic fertilizer to the growth and yield of lettuce (*Lactuca sativa* L.) in a hydroponic system at a greenhouse in Madiun, Indonesia.

MATERIALS AND METHODS

The research was conducted at the Green House, Faculty of Agriculture, Merdeka University Madiun, from December 2023 to January 2024. The altitude is 63 m above sea level, with an average temperature of 29^0-31^0 C.

The materials of research used are lettuce seeds, bokashi fertilizer, AB-Mix hydroponic nutrients, water, and rock wool media. The tools used were a DFT hydroponic installation made from Paralon, net pot, pH meter, water pump, digital scale, oven, and a camera. Experimental research using a two-factor Randomized Block Design was repeated three times. The first factor is Bokashi fertilizer, which consists of

3 levels, namely P_1 (1 kg), P_2 (2 kg), and P_3 (3 kg) per 30 liters of water. The second factor is dosage of NPK fertilizer, which has three levels of A_0 (0g), A_1 (1g), and A_2 (2 g) per 30 liters of water. Thus, there are nine treatment combinations and a control treatment using AB-Mix nutrition. Bokashi fertilizer is applied twice at planting time and 15 days after planting by wrapping it in a thin cloth. Meanwhile, NPK fertilizer is given directly to the media three times at planting, 10 and 20 days after planting.

RESULTS AND DISCUSSION

Interaction of bokashi and NPK: There are interactions for all parameters, namely plant length, number of leaves, leaf area, and plant fresh weight. The form of interaction at the age of 21 days after planting (dap) can be seen in Figure 1.

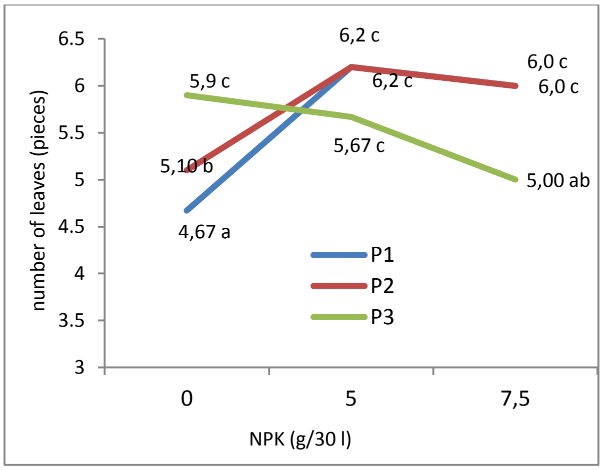


Fig 1. Interaction of bokashi fertilizer and NPK fertilizer on the number of lettuce leaves aged 28 days after planting.

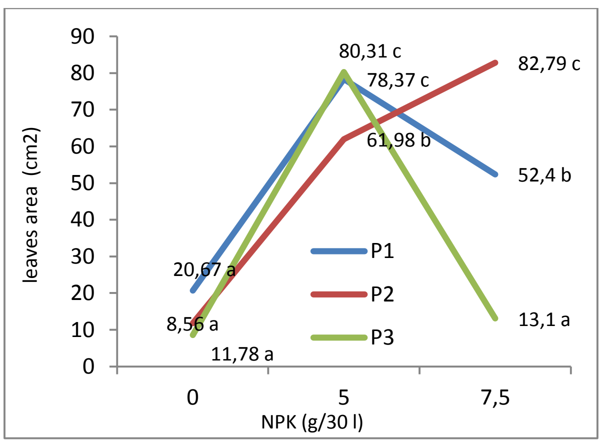


Fig 2. Interaction of bokashi fertilizer and NPK fertilizer on the lettuce leaves area aged 28 days after planting.

The high dose of bokashi stimulated leaf growth in the treatment without NPK and further decreased with increasing NPK dose. This shows that a large amount of micronutrients actually inhibits the development of the number of leaves.

In contrast to the low bokashi dosage (P1, P2), with increasing NPK, there is a nutrient balance to stimulate the growth of the number of leaves. The difference is insignificant, indicating that the number of leaves is more influenced by genetic factors than environmental factors. Statistical analysis of leaf area parameters showed an interaction between the treatment concentrations of bokashi fertilizer (P) and NPK fertilizer (A) at all ages of observation. Figure 2 presents the average area of lettuce leaves on bokashi fertilizer and NPK fertilizer, along with the form of interaction at the age of 28 days after planting.

Figure 3 shows that the response of bokashi to NPK fertilizer is very different between low and high doses of bokashi. At doses of 1 kg and 3 kg, the NPK range of 5 g showed high leaf area results, while at a dose of 2 kg, it still showed an increasing trend with the addition of NPK. This indicates that the availability of micro and macronutrients that are too high can inhibit the growth of leaf area. This also shows the importance of nutrient balance to support plant growth. The results of the statistical analysis of the solution's pH show that there is no interaction between the treatment concentrations of bokashi fertilizer (P) and NPK fertilizer (A). The average pH of the lettuce plant solution in bokashi fertilizer and NPK fertilizer is presented in Figure 4. Figure 3 shows that the bokashi doses have no effect on pH, while the addition of NPK significantly reduces the pH of the solution. Thus, judging from the pH of the solution, there is relatively no problem, but the addition of a small amount of calcium may require further study.

The statistical analysis results on plant fresh weight showed an interaction for plant fresh weight, while there was no interaction for dry weight. The form of interaction between the fresh weights of lettuce plants is presented in Figure 5. Meanwhile, the influence of each main factor is presented in Figure 6. It can be seen that at high doses (3 kg), adding 5 grams of NPK gave the best results, which decreased drastically with higher NPK doses. Meanwhile, at low doses (1 and 2 kg), the addition of NPK showed a significant increase in results. The best results are at low doses (1kg) with 5 grams of NPK. In Figure 5, Bokashi concentration increases, the dry weight decreases while increasing NPK increases the dry weight produced. Table 2 presents the results of statistical analysis comparing all treatment combinations to the AB-Mix control. For all growth parameters, using bokashi with the addition of NPK macronutrients can compete with using AB-Mix hydroponic instant nutrients. The best results were achieved at a bokashi dose of 2 kg with an NPK concentration of 1 gram (P2A1), which was not significantly different at a higher bokashi dose..

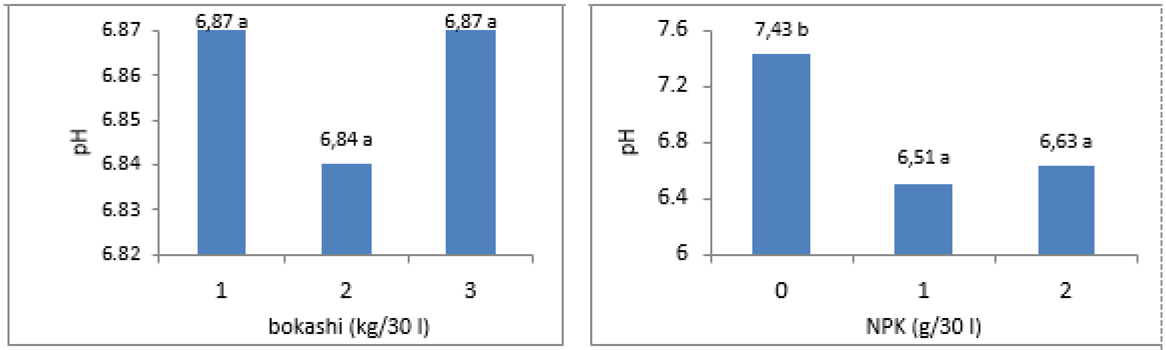


Fig 3. Effect of bokashi (left) and the effect of NPK (right) on the pH of the solution

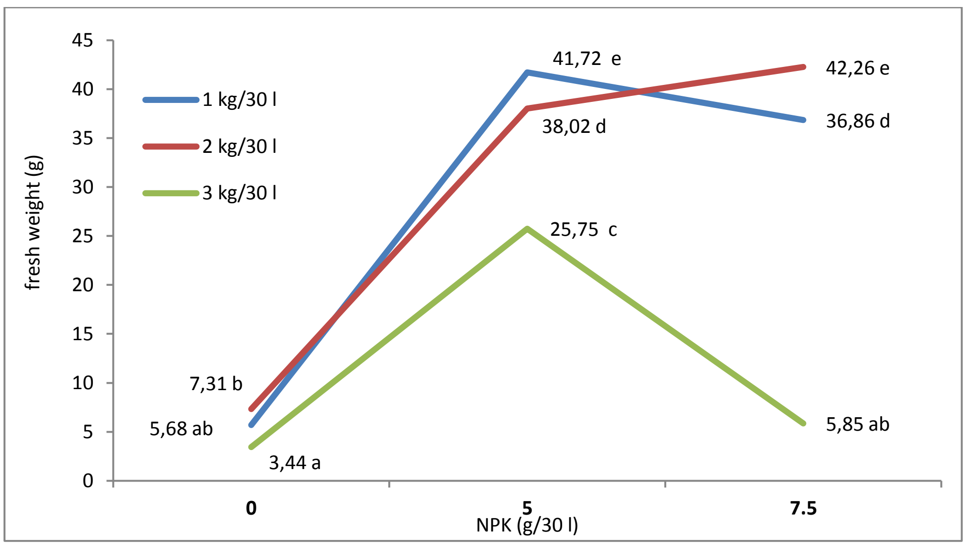
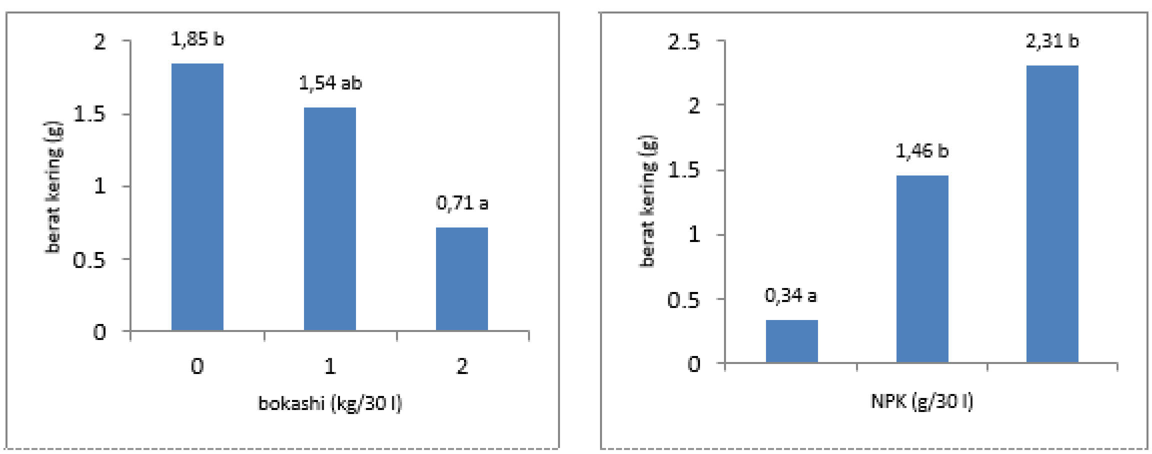


Fig 4. Interaction of bokashi and NPK fertilizer on the lettuce fresh weight



Note: Numbers followed by the same letter on each picture are not significant at 5% DMRT

Fig 5. Effect of bokashi and NPK fertilizer on the lettuce dry weight

Comparison to control: Table 2 shows that the use of bokashi with low doses of NPK is sufficient to fulfill the hydroponic nutrition of lettuce plants, no different from the control using AB-Mix Nutrition. The results of statistical analysis show that there are interactions in almost all observation parameters. In general, giving NPK significantly increases plant growth and yield. Still, at high NPK concentrations, growth tends to decrease, indicating that nutrient sufficiency has occurred at a bokashi concentration of around 2 kg and an NPK concentration of 1 gram. Providing bokashi has been proven to increase the growth and yield of lettuce plants because the nutrients in it can provide nutrients for plant growth, plant roots will develop well, and roots can absorb more nutrients, especially N nutrients, which will increase the formation of chlorophyll. So that photosynthetic activity increases (Zalna *et al.*, 2018). Using bokashi for hydroponic nutrition without adding the macronutrient NPK has been proven unable to support the optimal growth of lettuce plants. This indicates deficient macronutrient content, especially N, P, and K in bokashi. It is understood that these three elements are the main components for forming new cells. The elements N and P, in the form of bases N and phosphate, are essential constituents of DNA in the formation of new cells for plant growth. N, P, and K are the primary nutrients for plant growth. The N element is a nutrient that plays a role in forming plant vegetative organs and is the main element that forms amino acids and proteins. Nutrient K is essential in the process of forming peanut seeds together with nutrient P as well as being important as a regulator of various mechanisms in metabolic processes such as photosynthesis, nutrient transport from roots to leaves, translocation of assimilate from leaves to all plant tissues (Sutarto et al. 1988). N, P, and K are essential macronutrients for plants that function in plant cells' metabolic and biochemical processes. Nitrogen builds nucleic acids, proteins, enzymes, and chlorophyll. At the same time, phosphorus is a builder of nucleic acids, phospholipids, enzymes, proteins, and metabolic compounds and is part of ATP, which is essential in energy transfer (Uchida, 2000). Plants' absorption of N, P, and K nutrients is influenced by nutrient availability. Nutrient absorption by chili plants continues as long as the plants still need these nutrients for plant growth and development. Nutrient sources from organic fertilizer can be absorbed by plants directly compared to organic fertilizer, which requires a decomposition process first (slow release). However, intensive use of inorganic fertilizers, especially without being balanced with organic fertilizers, can increase residues, which slowly cause soil damage, including the soil becoming quickly hardened, less able to store water, and lowering soil pH (Riley, 2015). The use of bokashi in a hydroponic system shows that high concentrations suppress plant growth, and a concentration of 1-2 kg per 30 liters of water gives the best effect with the addition of a small amount of NPK, indicating that the micronutrient content of bokashi is quite large. Bokashi is a type of fertilizer that can replace the presence of artificial chemical fertilizers to increase soil fertility while repairing damage to soil properties due to excessive use of inorganic (chemical) fertilizers (Tufaila *et al.*, 2014).

Table 2. Comparison of observations of various growth parameters with AB-Mix control.

Treatment combination	**Plant length (cm)**	**Leaves number (pieces)**	**Leaves area (cm^2)**	**Fresh weight (g)**	**Root length (cm)**
P1A0	5,2ab	6a	16,79abc	5,29a	17,90ab
P2A0	4,03a	6a	10,67a	5,47a	18,33ab
P3A0	5,53ab	6a	13,54ab	5,66a	17,86ab
P1A1	11,51cd	7,3b	65,67d	36,05b	16,25ab
P2A1	12,50cd	7,23b	80,43d	35,04b	23,70ab
P3A1	12,20cd	7,33b	71,17d	34,39b	15,81ab
P1A2	8,61bc	6,43ab	49,54bcd	27,38b	11,78a
P2A2	8,92bcd	6,33ab	45,56abcd	28,07b	12,54a
P3A2	8,90bcd	6,33ab	52,73cd	29,52b	12,03a
Control (AB-Mix)	12,94d	6,61ab	81,88d	36,61b	26,10b

Note: Numbers followed by the same letter in the same column are not significant at 5% DMRT

Bokashi also contains effective soil microorganisms as decomposers, which can accelerate the decomposition process of organic material, thereby increasing the availability of N, P, and K nutrients for plants (Kaya, 2013). At high bokashi concentrations, the addition of NPK further reduces the growth and yield of lettuce plants, indicating that nutrient availability is too high, which is actually an overdose that negatively impacts the plants. It is stated that toxicity occurs if there are high amounts of nutrients in a plant and causes a decrease in development so that strategies and guidelines for better fertilizer use can improve soil quality and avoid detrimental results (Toor *et al.*, 2020). The comparison results with the AB-Mix control show that combining bokashi with NPK can compete with AB-Mix conventional hydroponic nutrition. This shows that hydroponics can use organic materials enriched with the macronutrient NPK. The micronutrient content of bokashi is thus complete enough to support the growth of hydroponic system plants as long as it is supplemented with macronutrients, especially NPK, in sufficient quantities. The application of bokashi fertilizer is one way to increase the nutrient content of plants because it can provide a source of carbon and nitrogen, facilitate germination, and increase plant yields (Putri *et al.*, 2023). Providing bokashi has been proven to increase plant growth and yield and improve germination, flowering, fruit formation, crop maturity, and photosynthetic capacity. The amount of nutrients absorbed by the roots will affect the amount of organic material and the amount of minerals distributed throughout the plant. Besides that, bokashi provides N, P, and K nutrients essential for shoot growth, root development, accelerating flowering, ripening, and root and seed formation (Sugiyarto *et al.*, 2023). Organic materials are also essential to maintain high yields (Yuliarta *et al.*, 2014). However, using too much fertilizer, both organic and inorganic, will suppress plant growth due to the toxicity it causes.

Conclusion: From the results of the analysis and discussion, it can be concluded:

1. The application of bokashi and NPK fertilizers significantly interacts with the growth and yield of lettuce.
2. Low-dose of Bokashi (1kg/30 l) plus 1 gram/30 l of NPK gives the best results, and the effect tends to decrease if more NPK is added.
3. At high bokashi doses (3kg/30 l), the addition of NPK does not significantly increase yields and even tends to reduce lettuce crop yields

Acknowledgement: We as authors would like to express our gratitude to the Merdeka Madiun University which has funded this research with contract number 021/SPKP2/PD/UNMER/LPPM/XI/2023

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