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The Effect of Azolla Compost and Inorganic Nitrogen Fertilizer on the Growth and Yield of Cucumber

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ABSTRACT

Cucumber is a popular vegetable that can be consumed fresh or processed into pickles, preserves, and other products. Efforts to enhance cucumber yield have been made through the application of Azolla compost and inorganic nitrogen (N) fertilizer. This study aimed to evaluate the interaction between different doses of Azolla compost and inorganic N fertilizer on cucumber growth and yield, as well as to determine the optimal doses of both fertilizers. The experiment was conducted from December 2021 to February 2022 in Medan Baru, Muara Bangkahulu District, Bengkulu City. A factorial randomized complete block design was employed with two factors: (1) Azolla compost doses (0 g plant^{-1}, 90 g plant^{-1}, 180 g plant^{-1}, and 270 g plant^{-1}) and (2) inorganic N fertilizer doses (0 g plant^{-1}, 0.9 g plant^{-1}, 1.7 g plant^{-1}, and 2.5 g plant^{-1}), resulting in 16 treatment combinations, each replicated three times. Data were analyzed using ANOVA at a 5% significance level, followed by Duncan's Multiple Range Test for significant variables. Results indicated that there were no significant interaction effects between Azolla compost and inorganic N fertilizer on cucumber growth and yield. The 180 g plant^{-1} dose of Azolla compost produced the best results in terms of vine length, leaf number, fruit weight per plant, and plant dry weight. However, inorganic N fertilizer had no significant effect on cucumber growth and yield. Further research is needed to explore the effects of inorganic N fertilizer and the potential of Azolla as an environmentally friendly organic fertilizer in sustainable agricultural systems.

Keywords: *crop yield enhancement, soil nutrient management, sustainable agriculture practices*

INTRODUCTION

Cucumber (*Cucumis sativus* L.), belongs to the Cucurbitaceae family, is widely recognized by Indonesian farmers. Botanist believed that cucumbers is as a native plant of India, specifically in the foothills of the Himalayas (Rukmana, 1994). In 1882, it spread to the Mediterranean region, including China, and overtime cucumber cultivation spread worldwide, particularly in tropical regions. Cucumber was known in China as early as the 2nd century BC. It is a versatile vegetable that can be consumed fresh, processed, pickled, or fermented. Beyond its use as a food item, cucumber offers many benefits in fields such as cosmetics, health sciences, and food processing.

Cucumber production in the Bengkulu Province has experienced a decline. Data from the Central Bureau of Statistics (BPS) showed that in 2017, production reached 8,685 tons from 1,287 hectares (6.75 tons ha^{-1}), but decreased in 2018 to 7,828 tons from 1,233 hectares (6.35 tons ha^{-1}) (BPS Bengkulu Province, 2018). Due to high market demand and declining production, efforts to increase yield are necessary, one of which is through the intensification of organic fertilizer application, specifically compost. Fertilization is essential in crop cultivation as it significantly influences crop growth and yield.

Compost is the result of the decomposition, decay, and breakdown of organic materials such as animal manure, leaves, and other organic matter

(Soeryoko, 2011). Azolla pinnata is one material that can be used to produce compost. According to Surdina *et al.* (2016), Azolla, which is rich in protein, is utilized as feed for fish and is also favoured by livestock such as cattle and poultry. In addition, Azolla is a type of water fern, can be used as organic fertilizer and establishes mutualistic symbiosis with nitrogen-fixing bacteria (N), providing nitrogen for plants. This symbiosis, known as *Anabaena azollae* can fix atmospheric nitrogen (N_2), making it available to plants (Sudjana, 2014). Azolla fertilizer has the advantage of accelerating plant propagation.

Azolla is a small plant with a length of 1.5-2.5 cm. Its roots are lateral, with a pointed or sharp appearance, resembling hair or fuzz floating on water. The leaves are small, about 1-2 mm long, and overlap each other (Sudjana, 2014). In addition, the upper surface of the leaves is green, brown, or reddish, while the underside is transparent brown. The leaves often appear maroon, covering the water's surface. When grown in full sunlight, especially in late summer and spring, Azolla can produce reddish anthocyanins in its leaves. According to Ramadhani *et al.* (2020), the application of 1.5 kg of Azolla compost per plot significantly improved the productivity of long bean plants. Similarly, research by Khairat *et al.* (2021) found that the application of 15 tons ha^{-1} of Azolla compost resulted in the highest plant height and fruit weight per plant in tomato crops. Several studies on inorganic fertilizers have also shown that the application of inorganic nitrogen (N) fertilizer can increase rice yields (Siregar & Marzuki, 2011), while 100 kg ha^{-1} of N fertilizer increased corn yield to 10.65 tons ha^{-1} (Saragih *et al.*, 2013). Additionally, the application of 92 kg ha^{-1} of inorganic N fertilizer significantly affected the plant height, number of leaves, fresh weight, and dry weight of mustard plants (Sarif *et al.*, 2015).

Azolla, when applied as green manure or compost, either alone or in combination, significantly impacts soil chemical properties, such as organic carbon (C), nitrogen (N), phosphorus (P), potassium (K), and cation exchange capacity (CEC) (Elmizan et al., 2014). Azolla and inorganic nitrogen significantly influence plant height and dry weight. The interaction between Azolla and inorganic nitrogen only affects plant dry weight (Gunawan & Kartina, 2012). Azolla application enhances plant height, while inorganic nitrogen increases plant dry weight. This indicates that the nitrogen content in Azolla promotes plant height, whereas nitrogen in inorganic fertilizer tends to increase dry weight.

The advantage of inorganic fertilizer is that it contains specific nutrients, such as nitrogen (N), NPK, or a combination of nutrients, allowing its use to tailor plant needs. Inorganic fertilizers are usually easily soluble, making them readily available to plants, and their use and transportation are more practical. However, inorganic fertilizers have disadvantages, such as being prone to leaching into the lower soil layers, making it inaccessible to water. Some types of inorganic fertilizers can lower soil pH or affect soil acidity, and excessive and continuous use without organic fertilizer can alter soil structure, chemistry, and biology (Zhao *et al.*, 2016).

Considering the advantages and disadvantages of both organic and inorganic fertilizers, a combination of the two is necessary. The combination of organic and inorganic fertilizers ensures optimal nutrient availability while reducing land or soil degradation. Organic fertilizers have the advantage of improving soil structure and microbiological activity. The appropriate dosage needs to be researched, as plants require specific amounts of nutrients for optimal growth and yield, and not all doses elicit a positive response. Research on the combination of Azolla compost and inorganic nitrogen fertilizer is still limited. Therefore, investigating the effects of Azolla compost and inorganic nitrogen fertilizer on cucumber cultivation is essential.

MATERIALS AND METHODS

This research was conducted from December 2021 to February 2022 in Medan Baru, Kandang Limun Subdistrict, Muara Bangkahulu District, Bengkulu City at an elevation of approximately 10 meters above sea level.

This study employed a factorial Completely Randomized Block Design (CRBD) with two factors. The first factor was the Azolla fertilizer dosage, consisting of four levels: A_0 = 0 g plant^{-1}, A_1 = 90 g plant^{-1}, A_2 = 180 g plant^{-1}, and A_3 = 270 g plant^{-1}. The second factor was the inorganic nitrogen fertilizer dosage, consisting of four levels:N_0 = 0 g plant^{-1}, N_1 = 0.9 g plant^{-1}, N_2 = 1.7 g plant^{-1}, and N_3 = 2.5 g/ plant. Thus, there were 16 treatment combinations, and each experimental unit was repeated three times, with each unit consisting of two polybags, resulting in a total of 96 polybags.

The planting medium consisted of topsoil obtained from the Experimental Station of the Faculty of Agriculture, University of Bengkulu. The soil sample was analysed in the Soil Science Laboratory of the University of Bengkulu to determine its chemical properties. The initial soil analysis results were used to calculate the required lime dosage. The topsoil was placed into polybags at a rate of 7 kg polybag^{-1}. The soil was mixed with dolomite at 4.30 tons ha^{-1} or equivalent to 13.6 g polybag^{-1} to neutralize the soil pH, along with cow manure to increase the organic carbon content in the soil. The application of dolomite and cow manure was done two weeks before planting, and Azolla fertilizer was applied one week before planting.

Cucumber seeds were planted in the polybags at a depth of approximately 1 cm, with three seeds per polybag. Thinning was performed in polybags with three seedlings, cutting two plants and leaving the best plant to grow. Pest and disease control was conducted organically using botanical pesticides or mechanically by manually removing pests. Replanting was carried out for dead plants, and no replanting was needed if plants had survived more than two weeks after planting. Inorganic nitrogen fertilizer was applied one week after planting. Stakes were installed when the plants were 10 days after planting (DAP), using bamboo stakes for each polybag. Cucumbers require abundant water supply, so watering was done conditionally, based on the dryness of the planting medium. During the vegetative growth stage, watering was done in the afternoon, while during the generative stage, watering was only done in the afternoon or based on weather conditions. Weed control in the polybags was carried out regularly, and the experimental area was weeded periodically based on the weed growth.

The vine length was measured from the soil surface to the highest growth point using a fabric tape measure. Measurements were taken from the second week after planting until the fourth week. After two weeks of growth, the number of fully expanded, fresh, and non-yellowing leaves was counted, with observations made from the second to fourth weeks after planting. The number of fruits per plant was recorded when the plants reached the harvest stage. The first harvest was conducted at 35 days after planting. Harvesting was done by cutting the fruit stems with scissors (Alvindo, 2020). Fruit harvesting was conducted every 1-2 days, with 1-3 fruits harvested per plant. Cucumbers were considered ready for harvest when they exhibited uniform light green coloration from base to tip and had no fine hairs or spines on their skin. Harvesting was conducted five times. Fruit length was measured by collecting all fruits from the plant and measuring from the base to the tip using a tape measure. Fruit diameter was measured at the middle of the fruit using a calliper. Fruit weight per plant was recorded by weighing all fruits harvested from the plant during each harvest using an analytical scale, and the average was calculated. Plant fresh weight was measured by weighing the entire plant, excluding the fruits, using a digital scale. Plant dry weight was obtained by placing the plant biomass in an oven until a constant weight was reached, and then weighing it with a digital scale. Marketable fruit weight was calculated by selecting fruits that met market standards. According to Hermawan (2015), marketable fruits must meet the following criteria: (a) no physical defects, (b) fruit age not exceeding 39 days, (c) green color and meeting harvest criteria, (d) fruit length of no less than 12 cm for Bandana F1 variety, and (e) fruit diameter of more than 15 mm.

Supporting data included the initial soil analysis results conducted in the Soil Science Laboratory at the University of Bengkulu, covering the levels of N, P, K, organic carbon (C), and soil pH. Rainfall and temperature data were obtained from BMKG Pulau Baai, Bengkulu. The data collected from observations were statistically analysed using analysis of variance (ANOVA) at the 5% significance level. Treatments showing significant effects were compared using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

General overview

Overall, the cucumber plants exhibited healthy and vigorous growth from the first week of planting. Throughout the study, there were minimal obstacles encountered. However, at 3 weeks after planting (WAP), cucumber beetles (*Epilachna sparsa*) attacked around 15% of the cucumber leaves. These pests caused damage when the plants began flowering. The cucumber beetles were controlled mechanically by manually removing the insects from the leaves and then killing them. During the harvesting period, approximately 5% of the cucumber fruits were found to be affected by fruit worms.

During the research period, the average monthly rainfall for December 2021, January 2022, and February 2022 was 392.3 mm, 242.6 mm, and 232.1 mm, respectively. The average daily temperature in December 2021 was 27.1 ^{o}C, in January 2022 was 27.1 ^{o}C, and in Febrruary 2022 it was 26.8 ^{o}C. Additionally, the average air humidity for December 2021, January 2022, and February 2022 was 83.4%, 82.9%, and 80.5%, respectively.

The data collected from each observation variable were then analyzed for variance. The results of the variance analysis (F-test) at a 5% significance level can be seen in Table 1. The variable "number of fruits per plant" produced a coefficient of variation greater than 30%, thus the variable was transformed using the formula $\sqrt{x} + 0.5$, resulting in a coefficient of variation less than 30%. The coefficient of variation indicates the accuracy and reliability of the conclusions drawn from an experiment. This coefficient is also expressed as a percentage of the overall experiment's mean (Harjosuwono *et al*., 2011; Gomez & Gomez, 1995).

Table 1. Summary of variance analysis results for growth and yield of Cucumber due to Azolla fertilizer and inorganic N fertilizer treatments

Variable	F-value			CV (%)
	Azolla	N anorganic	Interaction	
Vine length	42.10 *	1.15 ns	0.90 ns	14.18
Number of leaves	37.69 *	2.32 ns	1.03 ns	16.88
Stem diameter	42.10 *	1.15 ns	0.90 ns	14.18
Number of fruits per plant	6.60 *	1.59 ns	1.01 ns	16.79
Length of fruit	1.24 ns	1.04 ns	1.12 ns	5.98
Fruit diameter	0.02 ns	1.03 ns	0.72 ns	4.86
Fruit weight per plant	1.03 ns	0.20 ns	1.65 ns	11.5
Plant dry weight	14.67 *	1.63 ns	1.20 ns	28.53
Marketable fruit weight	2.15 ns	0.56 ns	0.96 ns	10.93

Note : * = significant ; ns = non-significant

The application of inorganic nitrogen fertilizer doses did not significantly affect all observed variables (Table 1). The application of inorganic nitrogen fertilizer at doses of 0 g/plant, 90 g/plant, 180 g/plant, and 270 g/plant did not enhance the growth and yield of cucumber plants. Nitrogen (N) is an essential nutrient; however, plants require a balance of other nutrients, such as phosphorus (P) and potassium (K). In growing media that already contain sufficient N, the addition of inorganic N does not significantly affect the growth and yield of cucumber plants. Similarly, if the availability of nutrients for cucumber growth and yield is inadequate, the results may be compromised. These findings differ from those of Ramasandy & Sumarni (2023), which demonstrated that inorganic nitrogen fertilizer doses significantly affected cucumber growth and yield.

Plants that receive an adequate supply of both macro and micronutrients will exhibit good growth and yield (Rismunandar, 2000). Nitrogen is a vital nutrient for plant growth, especially in the formation or growth of vegetative parts such as leaves, stems, and roots (Djajadirana, 2000). Furthermore, Farid *et al*. (2022) stated that the primary role of nitrogen in plants is to stimulate overall growth, particularly the development of stems, branches, and leaves.

Result of this study also revealed that there was no interaction between the two factors—Azolla fertilizer doses and inorganic nitrogen fertilizer—on any of the observed variables (Table 1). This was likely due to the inappropriate fertilizer rates. The role of each fertilizer applied exerted an independent effect on the plants. However, the slow decomposition process from the treatments provided may have delayed the availability of nutrients to the plants, thus delaying growth and production (Yulhasmir *et al*., 2021). Research consistently shows that while these two treatments independently enhance plant growth and nutrient uptake, their combined use does not always produce a synergistic effect, particularly regarding nitrogen uptake and yield, as observed in studies on other crops like maize and rice (Khair *et al*., 2021).

The effect of Azolla fertilizer dosage on the growth and yield of Cucumber

The analysis result indicate that the application of Azolla fertilizer dosage had a significant effect on vine length, number of leaves, number of fruits per plant, fresh plant weight, and dry plant weight (Table 1). The average growth of cucumber at each dosage of Azolla fertilizer is presented in Table 2.

The application of Azolla fertilizer at a dosage of 180 g plant^{-1} resulted in the highest average values for vine length, number of leaves, fresh plant weight, and dry plant weight.This is because the dosage applied meet the nutrient requirement of the plants.

The application of Azolla fertilizer affected vine length, which ranged from 72.58 cm to 143.5 cm. The highest growth was observed with the 270 g plant^{-1} dosage, reaching a height of 143.5 cm, but it was not significantly different from the 180 g plant^{-1} dosage and was significantly different from the 90 g plant^{-1} and 0 g plant^{-1} dosages. This is due to Azolla compost containing various essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients required by cucumber plants for growth. Plants will grow and produce optimally if they receive sufficient nutrients. Nitrogen is a primary nutrient for plant growth, generally essential for the formation or growth of vegetative parts such as leaves, stems, and roots (Uchida, 2000)

Table 2. The average growth of cucumber at each dosage of Azolla fertilizer

Azolla fertilizer dosage (g plant^{-1}	PT (cm)	JD	DB (cm)	BST (g)	BKB (g)
0	72.58c	10.04c	72.58c	62.70c	7.49 c
90	121.08b	17.70b	121.08b	96.17b	13.74 b
180	131.83ab	20.04ab	131.83ab	98.83b	13.74 ab
270	143.5a	21.91a	143.5a	124.31a	17.47 a

Note : Values followed by the same letter in the same column are not significantly different based on DMRT at the 5% level; PT = Vine length; JD = Number of leaves ; DB = Stem diameter; BST = Plant fresh weight; BKB = plant dry weight

The effect of Azolla dosage on the number of leaves showed the highest number of leaves at the 270 g plant^{-1} dosage (21.91), although it was not significantly different from the 180 g plant^{-1} dosage (20.01) but was significantly different from the 90 (17.70) and 0 g plant^{-1} dosages (10.04). This finding aligns with the study by Ahdi *et al*. (2021), which reported that the application of 16 tons ha^{-1} of Azolla resulted in the best number of leaves.

The effect of Azolla dosage on fresh plant weight showed that the highest fresh weight was achieved with the 270 g plant^{-1} dosage (124.31 g), which was significantly different from the 180 g plant^{-1} dosage (98.83 g), the 90 g plant^{-1} dosage (96.17 g), and the 0 g plant^{-1} dosage (62.70). The application of 270 g plant^{-1} of Azolla compost produced optimal results, likely due to the plant's nitrogen requirements being met during the generative growth phase. Fresh weight reflects the quality of the plant during the growing period up to harvest (Handriatni, 2008).

The effect of Azolla dosage on dry plant weight showed the highest dry weight at the 270 g plant^{-1} dosage (17.47 g), although it was not significantly different from the 180 g plant^{-1} dosage (13.74 g) but was significantly different from the 90gplant^{-1} dosage (13.74 g) and the 0 g plant^{-1} dosage (7.49 g). The application of Azolla significantly affected dry plant weight. This result is consistent with the study by Amir *et al*. (2012), which showed that the application of Azolla had a highly significant effect on the dry weight of harvested spinach.

The application of Azolla compost had a significant effect on the variable number of fruits per plant. This is likely due to the high number of flowers that bloomed and successfully underwent pollination, resulting in a higher percentage of fruit formation. Azolla doses of 270 g plant^{-1} (1.79) and 180 g plant^{-1} (1.79) produced the highest fruit yields, though they were not significantly different from the 90 g plant^{-1} dose (1.59) but significantly different from the 0 g plant^{-1} dose (1.36) (Figure 1).

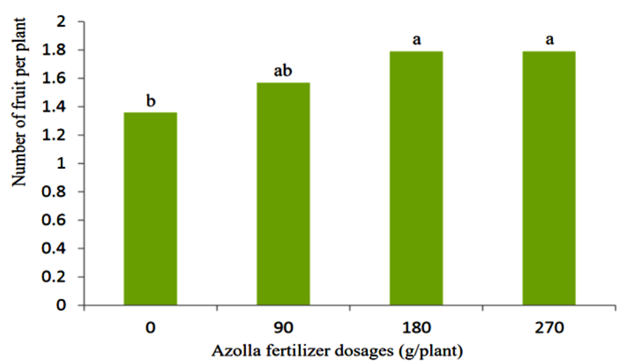

Figure 1. Relationship between Azolla fertilizer dosages and number of fruits per plant

Although there were no interactions between Azolla fertilizer and inorganic N fertilizer on growth and yields of cucumber (Table 1), it is interesting to discuss the profile of fruit number in each harvest. This is very important since this information will help the growers to manage efficient resource allocation, such as harvesting labour and transportation for marketing. Cucumber is typically harvested every other day (Burrows, 2021), in order to maintain the quality of the harvested fruits. Grant (2021) suggested that cucumbers that are kept on the vine for an extended period of time lose their fresh flavour due to a bitter taste. This study reveal that the peak of the harvest took place at the second harvest and drastically lowered at the fifth harvest.

Table3. Effect of treatments on fruit number in each harvest.

Treatments[1]	Fruit number harvesting at					Total
	35 DAT[2]	37 DAT	39 DAT	41 DAT	42 DAT	
A0N0	0	1	1	1	0	3
A0N1	1	1	1	6	0	9
A0N2	0	0	2	3	0	5
A0N3	1	3	0	1	1	6
A1N0	1	2	3	3	0	9
A1N1	1	4	2	2	0	9
A1N2	1	5	6	2	2	16
A1N3	1	2	1	3	2	9
A2N0	1	6	1	3	0	11
A2N1	3	4	2	5	3	17
A2N2	2	5	4	1	1	13
A2N3	3	2	2	3	2	12
A3N0	0	6	5	1	0	12
A3N1	0	8	4	3	0	15
A3N2	5	5	4	5	2	21
A3N3	4	6	4	2	2	18
Total	24	60	42	44	15	185

Notes:
[1]Treatment combinations, A_0=0 g plant^{-1}, A_1=90 g plant^{-1}, A_2=180 g plant^{-1}, A_3=270 g plant^{-1}, N_0=0 g plant^{-1}, N_1=0.9 g plant^{-1}, N_2=1.7 g plant^{-1}, and N_3=2.5 g plant^{-1}.
[2]DAT, days after transplanting

CONCLUSION

Based on this study, it is concluded that the interaction between Azolla compost dosage and inorganic nitrogen (N) did not have a significant effect on the growth and yield of cucumber plants. The application of Azolla compost at a dose of 180 g/plant resulted in the highest averages for vine length, number of leaves, and dry biomass weight. No optimal dosage of inorganic nitrogen fertilizer for cucumber growth and yield was identified. These findings suggest that Azolla compost can significantly enhance certain growth parameters of cucumber plants, and its use may reduce the reliance on inorganic nitrogen fertilizers. However, further research is needed to determine the appropriate combination of organic and inorganic fertilizers to maximize cucumber yield while maintaining sustainable agricultural practices.

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