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APPLICATION OF AZOLLA FERTILIZER ON VEGETATIVE GROWTH RED CHILI PLANT (CAPSICUM ANUUM [L.])

Eko Abadi Novrimansyah
[1]Agrotechnology Study Program, Faculty of Agriculture and Animal Science, Universitas Muhammadiyah Kotabumi
Email: eko.abadi.novrimansyah@umko.ac.id

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Abstract:

Red chili production in Lampung Province has declined, and low soil fertility is considered one of the main causes. Soil fertility may be improved by combining organic and inorganic fertilization. Azolla is an aquatic fern that fixes atmospheric nitrogen and releases it slowly into the soil, while also improving the biological, physical, and chemical properties of the soil. This study aimed to determine the effect of combined Urea and Azolla application on the vegetative growth of red chili cultivar TM 999. The research was conducted in Bandar Lampung from February to May 2025 using a single-factor treatment design arranged in a Randomized Complete Block Design with four replications. Homogeneity of variance was tested using Bartlett's test and model additivity using Tukey's test, followed by analysis of variance and mean separation with the Least Significant Difference test at the 5% level. The treatments consisted of six combinations of Azolla and Urea ranging from 0% to 100% Azolla. The results showed that the combination of 40% Azolla and 60% Urea increased the plant height of red chili cultivar TM 999 and did not differ significantly from the application of 100% Urea.

Keywords: *combination, Azolla, Urea, red chili, vegetative growth*

INTRODUCTION

Lampung Province is one of the regions in Indonesia where the population has a strong preference for red chili peppers. Red chili is a key ingredient in making chili sauce, a common accompaniment to meals. The red chili is a fruit and plant belonging to the *Capsicum* genus. Its fruit can be classified as a vegetable, a spice, or a condiment, depending on how it is used. Unripe chilies are typically green or white, while ripe ones can be red, yellow, orange, or purple. Generally, chilies do not exceed 10 cm in length, and their interior is predominantly filled with seeds. In reality, however, the color, shape, and size of a chili depend on its specific variety. As a condiment, spicy chili is highly popular in Southeast Asia for enhancing the flavor of food. In Padang cuisine, chili is even considered the tenth "staple ingredient" (surpassing the usual nine); it is extremely difficult to prepare Padang dishes without it. Chilies differ from other spices that merely provide a sensation of warmth; they possess a potent, hot, and pungent flavor that requires caution during consumption. This spiciness is caused by an active compound known as capsaicin. It is precisely this hot, spicy sensation that makes chili an essential ingredient in almost every spicy dish.

Large red chili peppers (*Capsicum annuum L.*) are a type of vegetable with high economic value. They contain various compounds that are beneficial to human health. Chili peppers are a vegetable commodity widely cultivated by farmers in Indonesia due to their high market price and various health benefits; notably, they contain capsaicin, a substance that plays a role in controlling cancer. Additionally, their high vitamin C content can meet daily nutritional needs, though they should be consumed in moderation to avoid gastric pain.

Chili peppers belong to the nightshade family (*Solanaceae*) and are easy to cultivate in both lowland and highland areas. These plants are rich in vitamins A and C and contain capsaicin an essential oil responsible for the characteristic spicy taste and heat sensation when used as a culinary seasoning. Because they are easy to grow, chilies can be cultivated for daily household needs, eliminating the need to purchase them at the market.

Chili plants thrive in loose, well drained, humus rich soil that is free from waterlogging; the ideal soil pH ranges from 5 to 6. For cultivation on dry land, the optimal planting time is at the end of the rainy season (March–April). Planting in October for a December harvest is another option that can potentially fetch higher market prices, although this method carries a greater risk of crop failure. Chili plants are propagated using seeds sourced from healthy, pest- and disease-free plants. The chili fruits selected for seed stock are sun-dried; with sufficient heat, they dry within five days, after which the seeds are extracted. Cultivating a one-hectare plot requires approximately two to three kilograms of chili fruit (yielding 300–500 grams of seeds).

Data from the Central Statistics Agency of Lampung Province indicate that chili production declined by 4,823 tons compared to the 2017 harvest (Badan Pusat Statistik, 2018). This drop in production may be attributed to soil fertility factors in the cultivation areas.

To enhance soil productivity, farmers can employ practices such as fertilization, the addition of organic matter and lime, the installation of drainage systems, and minimal tillage. In a specific sense, fertilization refers to the application of materials intended to provide nutrients to plants. Fertilizers can be applied in either inorganic or organic forms (Lingga & Marsono, 2000). Inorganic fertilizers are produced by blending nutrient-rich (inorganic) chemical ingredients. These fertilizers offer several advantages: application rates can be precisely controlled due to standardized nutrient content; nutrients are more rapidly available to plants; they are easy to transport; and transportation costs are significantly lower compared to organic fertilizers.

One widely used fertilizer is Urea (CO(NH2)2), which contains 45% nitrogen (N). Urea is hygroscopic, meaning it readily absorbs moisture from the air, which allows it to dissolve easily and be readily absorbed by plants (Palimbani, 2007). In addition to these advantages, inorganic fertilizers also have drawbacks notably, they contain only macronutrients and possess negligible or virtually no micronutrients. Furthermore, continuous use of inorganic fertilizers can degrade the soil if not balanced with organic fertilizers (Lingga & Marsono, 2000). Nitrogen deficiency can lead to stunted plant growth—characterized by smaller plant size, fewer leaves, and leaf chlorosis—and may even result in plant death (Wordpress, 2009).

Research by Mapegau (2007) indicates that nitrogen (N) fertilization affects the growth and yield of mung bean plants. Nitrogen can be obtained from either organic or inorganic fertilizers. Organic fertilizers—derived from animal manure, plant matter, and waste—serve as natural soil amendments that are superior to artificial or synthetic alternatives. Although organic fertilizers generally contain low levels of the macronutrients N, P, and K, which are released slowly to the plant, they provide adequate amounts of micronutrients essential for plant growth.Therefore, it is necessary to improve the soil's physical, chemical, and biological properties through the application of organic matter or green manure derived from plants.

Organic fertilizers can be combined with inorganic fertilizers to rapidly increase soil nutrient levels without compromising soil fertility. In general, the benefits of using organic fertilizers lie in their ability to improve the physical, chemical, and biological properties of the soil. Organic fertilizers should ideally be used as a supplement in combination with inorganic fertilizers. Applying a combination of inorganic and organic fertilizers is expected to rapidly increase soil nutrient levels without compromising the soil's natural fertility (Sutanto, 2002). One example of such an organic fertilizer is Azolla. Azolla possesses the ability to fix atmospheric nitrogen (N2) through its association with the cyanobacterium Anabaena azollae, which lives within its leaf cavities (Sutanto, 2002). With a nitrogen content of approximately 3–5%, Azolla can serve as a substitute for the nitrogen typically supplied by inorganic fertilizers such as Urea. The application of Azolla organic fertilizer can also create more favorable conditions for root growth (Hairiah, 2000; Kresnatita, 2009).

Inorganic fertilizer (Urea) provides sufficient nitrogen for plants; however, continuous use can reduce soil productivity. Organic fertilizer can be used as a supplement in combination with inorganic fertilizer to achieve optimal crop yields (Sutanto, 2002). Although the use of organic fertilizer Azolla does not guarantee an adequate supply of essential macronutrients for plants, it creates better conditions for root growth (Hairiah et al., 2000, cited in Kresnatita, 2009). Research on the combination of inorganic fertilizer Urea and organic fertilizer Azolla is crucial, aiming to reduce the Urea dosage without compromising plant growth and production. Cultivating Azolla in rice fields can loosen the soil and improve its physical properties and fertility. If Azolla is cultivated in a given year, the soil organic matter content increases by 0.09% the following year (Sutanto, 2002).

Azolla is a type of aquatic fern that thrives in aquatic environments and is widely distributed. Like leguminous plants, Azolla fixes atmospheric nitrogen (N2) through its association with the cyanobacterium, which resides within its leaf cavities (Sutanto, 2002). According to Khan (1983, cited in Sutanto, 2002), Azolla's nitrogen-fixing capacity ranges from 400 to 500 kg N/ha/year. Its capacity to fix atmospheric nitrogen exceeds the plant's own requirements; consequently, a portion of the fixed nitrogen is released into the growing medium or the surrounding environment. Azolla serves as an organic fertilizer and helps improve the physical, chemical, and biological properties of the soil. Physical improvements resulting from Azolla include enhanced aggregate stability, soil structure, and porosity, driven by a reduction in soil bulk density. Chemically, Azolla enriches the soil with macro- and micronutrients. From a biological perspective, the plant boosts soil microbial activity and suppresses weed growth. Azolla can also act as a filter to remove heavy metal contaminants from water. Furthermore, it is capable of suppressing mosquito breeding, particularly in calm or stagnant waters (Arifin, 1996). Research and experimental results indicate that the use of Azolla whether as a basal fertilizer or a supplementary fertilizer applied before and after planting can significantly increase rice yields. The quality of Azolla influences soil fertility; decomposition products supply nitrogen more rapidly when the C/N ratio is low (Sutanto, 2002).

Previous studies have examined organic and inorganic fertilizers separately, yet information on the optimum proportion of Azolla that can substitute Urea in red chili cultivation remains limited. This study therefore aims to determine the effect of combined Azolla and Urea application on the vegetative growth of the TM 999 red chili cultivar.

RESEARCH METHOD

This study was conducted in Bandar Lampung from February 2025 to May 2025. The tools used in this study included writing instruments, a ruler, a soil sieve, and a hoe. The materials used were red chili seeds (cultivar TM 999), polybags, fresh Azolla organic fertilizer, and inorganic fertilizers (Urea, TSP, and KCl).

The treatment design was structured as a single-factor design. Treatments were applied to experimental plots arranged in a Randomized Complete Block Design (RCBD) with four replications for each treatment. Homogeneity of variance among treatments was tested using Bartlett's test, and model additivity was tested using Tukey's test. When these two assumptions were met, analysis of variance was performed, and mean separation was conducted using the Least Significant Difference (LSD) test at the 5% level. The treatments applied are presented in Table 1.

Table: 1 Fertilizer treatment combinations applied in the study

Treatment	Azolla	Urea
P1	0 g (0%)	12.60 g (100%)
P2	22.80 g (20%)	10.08 g (80%)
P3	45.60 g (40%)	7.56 g (60%)
P4	68.40 g (60%)	5.04 g (40%)
P5	91.20 g (80%)	2.52 g (20%)
P6	114.00 g (100%)	0 g (0%)

Note: P1 = 0% Azolla + 100% Urea; P2 = 20% Azolla + 80% Urea; P3 = 40% Azolla + 60% Urea; P4 = 60% Azolla + 40% Urea; P5 = 80% Azolla + 20% Urea; P6 = 100% Azolla + 0% Urea.

The variables observed in this study were as follows. Plant height was measured from the soil surface to the highest leaf growth point when the plant produced its first flower (maximum vegetative stage) and recorded in centimeters. The number of branches was determined by counting all branches produced by the plant at the maximum vegetative stage, that is, upon the emergence of the first flower. The number of leaves was determined by counting all leaves produced by the plant at the same stage.

FINDINGS AND DISCUSSION

Analysis of variance regarding the effect of applying a combination of Azolla and Urea, as well as their individual applications, showed a significant effect at the 1% level on plant height, whereas the effects on the number of branches and the number of leaves were not significant (Table 2).

Table: 2 Analysis of variance of the effect of combined and single applications of Azolla and Urea fertilizers on the observed variables of red chili (Capsicum annuum [L.]) cultivar TM 999

No	Variable	F value (Treatment)
1	Plant height	16.35 **
2	Number of branches	ns
3	Number of leaves	ns

*Note: ** = significant at a = 1%; ns = not significant.*

Plant Height

Post-hoc test results using the LSD test at the 5% level (Table 3) showed no significant differences in plant height among treatments P1, P2, and P3. The lowest plant height was recorded in the treatments with the highest proportion of Azolla.

Table: 3 Effect of the combined application of Urea and Azolla on the plant height of red chili cultivar TM 999

Treatment	Plant height (cm)
0% Azolla + 100% Urea (P1)	61.89 a
20% Azolla + 80% Urea (P2)	60.21 a
40% Azolla + 60% Urea (P3)	60.26 a
60% Azolla + 40% Urea (P4)	57.49 b
80% Azolla + 20% Urea (P5)	57.71 b
100% Azolla + 0% Urea (P6)	57.54 b
LSD 5% = 1.58	

Note: Means followed by the same letter do not differ significantly according to the LSD test at a = 5%.

Number of Branches and Number of Leaves

The mean number of branches and leaves produced by red chili plants under each fertilizer combination is presented in Table 4.

Table: 4 Effect of the combined application of Urea and Azolla on the number of branches and leaves of red chili cultivar TM 999

Dose of Azolla and Urea	Number of branches	Number of leaves
0% Azolla + 100% Urea (P1)	11	133
20% Azolla + 80% Urea (P2)	10	127
40% Azolla + 60% Urea (P3)	10	131
60% Azolla + 40% Urea (P4)	11	126
80% Azolla + 20% Urea (P5)	11	127
100% Azolla + 0% Urea (P6)	11	122

Discussion

Fertilization plays a crucial role in plant growth and development. Red chili plants require nitrogen fertilizer to stimulate their early growth. According to Wordpress (2009), nitrogen fertilizer requirements range from 10 to 25 kg/ha. Nitrogen fertilizer can be applied in either organic Azolla or inorganic Urea forms. The use of Azolla as a substitute for Urea is expected to reduce reliance on Urea as a nitrogen source for red chili plants.

Fertilization plays a crucial role in enhancing plant growth and development. The application of a combination of Azolla and Urea aims to reduce the continuous reliance on inorganic fertilizers as a nitrogen source for red chili plants. Inorganic fertilizers provide essential nutrients to plants rapidly, whereas organic fertilizers release nutrients slowly and in smaller quantities into the soil solution, thereby increasing the overall nutrient content in the soil. Azolla fertilizer helps create favorable soil conditions for root development. Enhanced root development leads to increased nitrogen uptake, which significantly influences plant growth and yield (Mukhlis, 1993). Combining organic and inorganic fertilizers has been reported to yield optimal results (Rukmana, 1995). Nitrogen (N) from urea fertilizer is rapidly available for plant uptake, whereas Azolla slowly releases small amounts of N into the soil solution, thereby increasing soil nitrogen content.

Regarding plant height, treatment P1 resulted in the greatest height (61.89cm), followed by P3 (60.26cm) and P2 (60.21cm). Treatment P4 yielded the lowest plant height (57.49cm), a value that did not differ significantly from those of P5 (57.71cm) and P6 (57.54cm). Treatment P3 (40% Azolla + 60% Urea) produced a plant height comparable to that of treatment P1 (0% Azolla + 100% Urea). These results indicate that the use of an Azolla combination can replace 40% of the Urea requirement.

The addition of organic matter significantly aids in the rehabilitation of degraded soil, the use of organic fertilizers helps retain nutrients prone to loss and facilitates nutrient availability, thereby enhancing fertilization efficiency. This is supported by findings from Rukmana (1995, cited in Kresnatita, 2009), which indicate that achieving maximum crop yields requires a balance between inorganic and organic fertilizers so that they can complement each other.

Nitrogen (N), derived from either organic or inorganic sources, plays a role in increasing chlorophyll content; consequently, when N is available in sufficient quantities, the rate of photosynthesis rises, leading to greater photosynthate production and an increased rate of pod formation, accompanied by larger seed size (Kresnatita, 2009, cited in Septiadi, 2010).

Regarding the plant height variable observed in this study, the nitrogen deficit resulting from reduced Urea usage could be compensated for by adding nitrogen from Azolla up to a proportion of 40%; this achieved plant heights comparable to the treatment using 0% Azolla and 100% Urea. Increased nitrogen availability in the soil enhances the plant's capacity for nitrogen uptake, thereby promoting better plant growth (Aribawa, Kartini, & Kariada, 2003). This is because nitrogen plays a direct role in protein synthesis and the improvement of vegetative growth. Azolla releases nitrogen slowly because it is an organic material that requires a decomposition process to provide nutrients to plants. The process of photosynthesis proceeds effectively when necessary nutrients are available in sufficient quantities, thereby ensuring an adequate supply of organic compounds for synthesis. The products of this assimilation—namely starch, proteins, and lipids—are utilized by the plant for cell division across its tissues, cell enlargement, and the replacement of damaged cells.

Nitrogen (N) is crucial for plant growth and development when a plant's nitrogen requirements are met, these processes proceed optimally. Plant height is a growth outcome that relies heavily on the quality of the vegetative phase. Increases in plant height are typically accompanied by a rise in the number of branches and leaves stimulating profuse flowering which ultimately results in an abundant yield of well-filled pods.

Regarding the number of branches, treatment P1 yielded the highest count 11 branches followed by treatments P4, P5, and P6, which also recorded 11 branches. Treatment P2 produced the lowest number of branches 10, a figure not significantly different from that of treatment P3 10 branches. Treatment P6 (100% Azolla + 0% Urea) resulted in a number of branches equivalent to that of treatment P1 (0% Azolla + 100% Urea). These results indicate that Azolla can fully replace Urea (100% substitution) in terms of the number of branches.

According to WordPress (2009), one symptom of nitrogen (N) deficiency is that plant leaves turn a pale yellowish color. In cases of severe deficiency, the leaves dry out, starting from the bottom and progressing upwards. Plant growth becomes slow and stunted. Fruit development is imperfect or poor, and the fruit often ripens prematurely.

Regarding the leaf count variable, treatment P1 yielded the highest number 133 leaves, followed by P3 131 leaves, P2 and P5 127 leaves, P4 126 leaves, and finally P6 122 leaves. Treatment P6 produced the lowest leaf count 122 leaves, a figure that did not differ significantly from that of P1 133 leaves. Treatment P6 consisting of 100% Azolla and 0% Urea was able to produce a leaf count comparable to that of treatment P1 (0% Azolla and 100% Urea). These results indicate that the use of an Azolla combination can fully replace the role of Urea (100% substitution) regarding the leaf count variable.

While the combination of Azolla (organic) and Urea (inorganic) successfully compensated for the nitrogen supply from Urea with respect to plant height, it did not achieve the same results for the number of branches and leaves. Azolla is an organic material with a lower capacity to supply nitrogen to plants compared to Urea. This finding aligns with Novizan (2002), who stated that organic materials must undergo decomposition before the nutrients within them become available to plants. Consequently, a proportion of Azolla exceeding 40% was not able to meet the nitrogen demand of red chili plants during the vegetative phase.

CONCLUSION

Based on the research results and discussion, it can be concluded that the combined fertilizer treatment of 40% Azolla and 60% Urea was able to enhance the vegetative growth, particularly the plant height, of red chili cultivar TM 999, and did not differ significantly from the treatment using 0% Azolla and 100% Urea. However, the fertilizer combinations did not significantly affect the number of branches and the number of leaves. These findings indicate that Azolla can substitute up to 40% of the nitrogen supplied by Urea in red chili cultivation, which offers an opportunity to reduce dependence on inorganic fertilizers while maintaining soil quality. Further studies are recommended to examine the effect of the same fertilizer combinations on the generative phase and yield of red chili, as well as on longer-term changes in soil chemical properties.

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