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Research Article

Use of Azolla in organic farming on availability and uptake of N, P, K of rice paddy (*Oryza Sativa*, L.)

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Abstract
Organic fertilization is very important to maintain sustainable land and environmental productivity. Organic fertilizer from Azolla has the advantage of increasing soil fertility by increasing nutrient availability. This study aimed to determine the effect of Azolla application on the availability and uptake of N, P, and K of Inpari 32 variety rice plants. This research used 9 treatments: (T_0= control, T_1= 90 kg/h NPK, T_2= 45 kg/h NPK, T_3= 10 t/h Manure, T_4= 2 t/h Manure + 90 kg/h NPK, T_5= 10 t/h Rice straw compost, T_6= 2 t/h Rice straw compost + 90 kg/h NPK, T_7= 10 t/h Azolla, T_8= 2 t/h Azolla + 90 kg/h NPK) with as control and 3 replications, so there were 27 experimental plots. This research was located in the paddy field of Madiun Regency, East Java. The results showed that Azolla, manure, and straw compost at a dose of 10 t/ha increased soil C-organic, soil Cation Exchange Capacity (CEC), and soil pH, which was still in the neutral range. Azolla fertilizer increased the highest soil total N compared to cow manure and straw compost and increased the efficiency of NPK fertilizer use. Azolla (T_7) increased soil available P (27.02 ppm) and exchangeable K (17.63 me/100g soil). Azolla had the highest available P effect. Azolla (T_7) and manure (T_4) were affected by increasing K-exchange. Azolla fertilizer, manure, and rice straw compost increased vegetative plant growth (plant height, number of tillers, shoot and root biomass). Among the three, Azolla fertilizer had the highest effect. Organic fertilization affected N, P, and K uptake, which was highest in Azola fertilizer (T_7). For manure, varied NPK fertilizer (T_4) just showed an increase in P uptake, and compost fertilizer varied NPK fertilizer (T_6) showed a rise in K uptake. A positive relationship existed between the availability and uptake of nutrients N, P, and K.

Keywords: Azolla, Inpari 32 variety rice, Nitrogen, Organic fertilizer, Rice field

INTRODUCTION

Indonesia is one of the countries that use chemical fertilizers to increase nutrient availability in inappropriate amounts, which can cause land degradation. About 48.3 million/ha or 25.1% of Indonesia's land area has been degraded (Darusman *et al.*, 2021). Currently, about 70% of rice fields in Indonesia contain low organ-

ic content [<1.5% organic carbon (C)], which can significantly reduce fertilizer use efficiency (Setiawati *et al*., 2020). In this case, organic farming is needed to maintain the health and sustainability of the land by adding organic fertilizers (Durán-Lara *et al*., 2020). Organic farming is needed in this case to maintain the health and sustainability of the land by adding organic fertilizers and will dismiss concerns of environmental pollution (Santhiya and Jeeva, 2022). Organic farming is done without applying chemicals and replacing them with natural ingredients (Uhunamure, 2021). According to Mahmood *et al*. (2017), adding organic fertilizers can increase nitrogen efficiency, micro and macronutrient recovery, and P dissolution and K availability. Organic fertilizers come from biological or living materials, such as manure from livestock such as cows and goats, compost from agricultural waste such as straw, and green manure from plants such as beans and Azolla (Sharma, 2017). Manure is a source of organic fertilizer commonly used by farmers. It has a relatively high nutrient content and, through the mineralization process, will release nutrients, especially N, P, and K (Suntoro *et al*., 2018). As a biofertilizer, Azolla is believed to have rapid decomposition and efficient nitrogen availability for rice plants (Mazid and Khan, 2015). Azolla is a water fern that can fix nitrogen. Azolla contains 4-5% nitrogen and 0.5-0.9% phosphorus. According to Thapa & Poudel (2021), Azolla can fix the presence of nitrogen due to its symbiotic relationship with *Cyanobacteria* and is used as a biofertilizer in rice fields. According to Youssef *et al*. (2021), Azolla is an essential source of N, the tissue will decomposed in 8-10 days and N is released into the soil so that it is available for plants to absorb. So, applying Azolla free-floating water spikes as a biofertilizer can be an alternative to increase rice yield without damaging the environment.

Plants that lack P elements can result in growth that is not optimal, or the potential yield is not optimal or does not complete the normal reproductive process Mayendra *et al*. (2019). The nutrient element potassium (K) is one of the essential elements that plants need as one of the supporters of plant growth and development. The main functions of K include helping root development, helping the process of protein formation, increasing plant resistance to disease, and stimulating seed filling. The amount of K in the soil that plants can absorb is small. In addition to the low availability of K, the availability of K in the soil is reduced due to three things, namely K uptake by plants (harvesting), leaching of K by water, and soil erosion (Al Mu'min and Yuniarti, 2016). Azolla can improve soil fertility by increasing the availability of nitrogen, organic carbon, availability of P and K elements (Putra and Tyasmoro, 2013). Azolla production technology is simple and not very expensive and, at the same time, very efficient in terms of biomass accumulation and nitrogen fixation. The rice growing season is also conducive to Azolla plant growth. Multiple applications have no negative influence on rice plants. Azolla organic fertilizer can increase the organic carbon content to maximize nutrients in the soil (Setiawati *et al*., 2020). This study aimed to determine the effect of Azolla application on the availability and uptake of paddy rice plants N, P, and K.

MATERIALS AND METHODS

Time and place of research

The present study was conducted in an organic rice field in Bantegan Village, Wungu District, Madiun, East Java. The experiment was carried out during the rainy season in May-August 2022. Soil and plant analysis was conducted at the Soil Chemistry and Fertility Laboratory, Faculty of Agriculture, Sebelas Maret University, Surakarta.

Experiment method

The experiment was conducted in the field with a Randomized Complete Block Design (RCBD). There were 9 treatments with 3 blocks and 27 experimental plots. Plots measured 2.5 m x 2.5 m. Rice plants were planted with a spacing of 20 x 20 cm. The treatments used are shown in Table 1.

Soil (disturbed soil) was taken from each plot to a depth of 30 cm. Tillage was done by ploughing until muddy and leveling the soil. Organic fertilizer application was done after Tillage. Inorganic fertilization is done once, 14 days after planting (DAP). Maintenance includes irrigation, weeding, replanting, and pest and disease control. The maximum vegetative phase is at the age of 60 days; in this phase, plant sampling and soil sampling are carried out, including pH (electrometry); CEC (ammonium acetate saturation method); C-Organic (Walkey and Black method); Soil N-Total (Kjeldahl method); Available P (Olsen method); Available K (1N Ammonium Acetate Extraction method), and analysis of upper plants including Plant N-Tissue (kjeldahl method); Plant Tissue P and K (HNO_3 and $HClO_4$ methods) (Balittanah (Soil Research Center), 2009).

Data analysis

Observation data were analyzed with IBM SPSS Statistic 20 using Analysis of Variance (ANOVA) with a 95% confidence level. Suppose the treatment has a significant effect on the variable. In that case, it is continued with the Duncan Multiple Range Test (DMRT) mean comparison test and correlation test to determine the closeness of the relationship between the observed variables.

Table 1. Treatments tested in the study

No.	Treatment	Dose	
		Organic fertilizer (t/h)	Inorganic fertilizer (kg/h)
T_0	Control	0	0
T_1	90 kg/h NPK	0	90
T_2	45 kg/h NPK	0	45
T_3	10 t/h Manure	10	0
T_4	2 t/h Manure + 90 kg/h NPK	2	90
T_5	10 t/h Rice straw compost	10	0
T_6	2 t/h Rice straw compost + 90 kg/h NPK	2	90
T_7	10 t/h Azolla	10	0
T_8	2 t/h Azolla + 90 kg/h NPK	2	90

Description: Organic fertilizer= Manure, Rice straw compost, Azolla; Inorganic fertilizer= NPK Phonska; Manure = Goat + cow dung waste.

RESULTS AND DISCUSSION

Soil characteristics

The soil at the research site was an organic rice field with vertisols (Soil Survey Staff, 2022), with the main characteristics of slightly black soil and its wrinkle growth properties. The land utilization used was rice cultivation with a rice-paddy-paddy pattern. Initial soil characteristics affect the sustainability of rice cultivation. Therefore, an initial soil analysis was conducted to determine the initial soil characteristics.

Table 2 shows that the soil in the study area had a pH of 6.88, which is classified as neutral and neutral, with a cation exchange capacity of 11.87, classified as low P and K, classified as medium and low and medium N-total. This is supported by similar research from Salman and Suntari (2023) who stated that vertisols have a pH between 6.0 and 8.2 and a low to moderate N-total content. So, additional nutrients from outside in the form of fertilizer are needed to maximize the growth and yield of rice plants.

Effect of treatment on soil chemical properties

Adding organic matter from manure, straw compost, and Azolla showed increased soil pH. The application of 10 t/h Azolla (T_7) showed a higher effect of 7.15, still in the neutral range compared to other treatments (Table 3). However, this increase does not jeopardize soil quality because the value is still within the neutral range. The sensitivity of soil pH to organic amendments is mainly due to the low buffering capacity of the soil (Angelova *et al*., 2013). The ideal soil condition for plant growth is when the soil pH is on the neutral scale (pH 6.5 - 7.8). According to Neina (2019), soil pH is described as a "*master soil variable,*" meaning it affects the soil's biological, chemical, and physical aspects. Soil conditions at this neutral pH significantly affect the optimal availability of nutrients and plant growth.

Table 2. Soil characteristics of Wungu rice field, Madiun, East Java

Parameters	Value	Class
N-Total (%)	0.23	Medium
Available P (ppm)	13.46	Medium
Exchangeable K (me/100 g soil)	13.26	Low
C-Organic (%)	1.50	Low
CEC (me/100 g soil)	11.87	Low
pH	6.88	Neutral

Description: Marking according to Soil Research Center (2009).

provision of Azolla had a real influence on the results of soil organic carbon. Azolla 10 t/h (T_7) affects C-organic 2.03% or an increase of 0.52%, and the highest in the treatment of straw compost is 10 t/h (T_5) with an average of 2.11% or an increase of 0.61%. According to Simarmata *et al*. (2023), the increase in soil organic carbon with Azolla treatment occurs due to the decomposition process of Azolla, which will increase the availability of soil C-organics. Azolla's high organic C content contributes to the increase in organic C. According to Thapa and Poudel (2021), 90% of Azolla is degraded in 4 weeks. The process of degradation and mineralization will produce soil organic C. This is in line with previous research by Simarmata *et al*. (2021) that the application of 10 t/h Azolla can increase soil organic carbon by 0.30%. Applying inorganic fertilizers alone gives results that are not significantly different from the control or no treatment because it does not contain organic matter. Chandini *et al*. (2019) stated that chemical fertilizers could could cause soil acidification, reducing organic matter, humus, and beneficial organisms.

Organic matter contributes significantly to soil CEC. The increase in soil exchange capacity generally comes from colloidal humus. So, organic fertilizers play an essential role in increasing soil CEC. Syamsiyah *et al*. (2017), Azola and manure are sources of soil organic matter, and the decomposition process will increase negatively charged functional groups, thus increasing their ability to exchange cations. Based on the research

Table 3. Effect of treatment on soil chemical properties and nutrient availability

No.	Treatment	pH H_2O	Organic C	CEC	Total N	Available P	Exchangeable K
			(%)	(me/100 g)	(%)	(ppm)	(me/100 g)
T_0	Control	6.99^{a}	1.51^{a}	12.89^{a}	0.26^{a}	14.52^{a}	14.32^{a}
T_1	90 kg/h	6.99^{a}	1.53^{a}	13.69^{ab}	0.32^{bc}	20.36^{b}	16.68^{bc}
T_2	45 kg/h NPK	7.08^{abc}	1.56^{a}	15.5^{c}	0.36^{de}	20.80^{b}	15.91^{b}
T_3	10 t/h Manure	7.12^{bc}	1.97^{bc}	14.56^{bc}	0.34^{cd}	19.19^{ab}	17.02^{bc}
T_4	2 t/h Manure + 90 kg/h NPK	7.09^{abc}	1.99^{bc}	15.14^{c}	0.37^{de}	27.74^{c}	17.80^{c}
T_5	10 t/h Rice straw compost	7.07^{abc}	2.11^{d}	14.53^{bc}	0.30^{b}	22.92^{bc}	16.67^{bc}
T_6	2 t/h Rice straw compost + 90 kg/h NPK	7.04^{ab}	1.87^{b}	14.03^{b}	0.37^{de}	23.20^{bc}	17.31^{c}
T_7	10 t/h Azolla	7.15^{c}	2.03^{bc}	15.3^{c}	0.36^{de}	27.02^{c}	17.63^{c}
T_8	2 t/h Azolla + 90 kg/h NPK	7.13^{bc}	1.96^{bc}	15.47^{c}	0.38^{e}	23.09^{bc}	17.42^{c}

of Sardiana and Kusmiyarti (2021), the organic C and cation exchange capacity in organic systems was significantly higher than in conventional systems due to the addition of organic fertilizer.

Soil nutrient availability

Plant growth and production can be achieved if the soil has enough nutrients to be absorbed by plants. Among the organic fertilizers used, Azolla fertilizer contributed higher total N in the soil than cow dung and straw compost. The availability of nutrients is one of the important factors supporting plant growth. The results showed the best results by Azolla 2 t/h + compound NPK 90 kg/h (T_8) with a value of 0.38%. According to Suntoro (2023) in Prihandarini , floating water fern or Azolla is a nitrogen-fixing plant that contains 3.4% nitrogen based on its dry weight. However, the 10 t/h Azolla (T_7) treatment only gave an average of 0.36%. This could have happened because Azolla fertilizer, included in organic fertilizers, releases complete nutrients such as N, P, and K in an indeterminate amount, relatively smaller and slowly available. Research by Thapa and Poudel, (2021) shows that Azolla pinata grown in rice fields can fix N on an average of 0.3-0.6 kg/h per day. Similarly, Singh has reported the ability to fix N 2.3 h/ day in fallow fields. As green manure in saturated soils, Azolla results in rapid mineralization, releasing 60-80% N within two weeks. Thus, According to Syamsiyah *et al*. (2017), Azolla, a widespread, free-floating aquatic fern, offers significant potential as a source of N in rice production. The NPK fertilizer used was a fertilizer that contained the highest amount of N, namely 15%. Inorganic fertilizers can provide higher N nutrients than organic fertilizers. According to Hernández *et al*. (2016), inorganic fertilizers are more quickly available to plants. Most of the N nutrients can be lost due to leaching. According to Selim (2020), inorganic fertilizers are more quickly lost due to leaching and subsurface runoff; the addition of organic fertilizers can increase physical fertility and absorption so that inorganic fertilizers are not easily washed away. According to Thapa and Poudel (2021), the physiological efficiency of using Azolla and N fertilizer was significantly higher than N-urea alone. Integrating organic and inorganic fertilizers is desirable to maintain crop yields and soil health. According to Yao *et al*. (2018), Azolla is symbiotic with Anabaena in binding free N in the air. Azolla and Anabaena azollae symbiosis can be bound to 100-170 kg N/h per year or 30-100 kg N/h/plant. Setiawati *et al*. (2020), Sesbania is an ideal green manure because it grows fast, decomposes quickly, and can maintain soil moisture and induce organic matter and N in the soil. Azolla can accumulate K in its tissues in low K environments; it decomposes rapidly and releases N, P, and K nutrients into the field after the field water is drained (Santhiya and Jeeva, 2022). The highest available P and K values were in the manure + NPK variation treatment (T_4), with available P values of 27.74 ppm and exchangeable K of 17.806 me/100 g soil. Azolla application treatment has the second highest value with an available P value of 27.0267 ppm and an exchangeable K value of 17.633 me/100 g soil. Azolla treatment can offset the results of the treatment of 1/5 manure + NPK (T_4), which has the highest value. According to Setiawati (2014), the treatment of *Azolla pinnata* and biological fertilizer gives an independent effect that significantly increases the content of soil available P. The content of soil available P in the Azolla pinnata 3 t/h treatment increased by 42.8% compared with no Azolla. Treatment with biological fertilizer at a dose of 10 t / h increased the soil's available P content by 72.1% compared with no natural fertilizer. These results show that *Azolla pinnata* and biofertilizers significantly increase soil available P content.

According to Sudadi *et al*. (2014), the highest K-exchange in P2 (Azolla inoculum dose of 500 g/m2, natural phosphate equivalent to 150 kg / h SP-36, husk

ash equivalent to 100 kg/ha KCl) of 0.46 me%, this is thought to be due to the higher the provision of Azolla than the K content in the soil will be higher. Azolla has a high K content. According to Ismoyo *et al*. (2013), giving Azolla compost increases the organic material in the soil to increase microbial activity that can help release K nutrients bound in the soil and according to Thapa and Poudel (2021), Azolla can accumulate K in its tissues in low K environments; it decomposes rapidly and releases N, P, and K nutrients into the field after the field water is drained.

Maximum vegetative plant growth

Rice growth rate can be influenced by internal influences, such as genetic traits or agronomic characteristics, and external influences, such as environmental conditions, biotic factors, chemical fertilization, or biological (Setiawati *et al*., 2020). Maximum growth was observed after the plants were 60 days old, and the meters observed included plant height, upper plant dry weight, and the number of tillers per clump. The Analysis of variance showed that all treatments had significant differences, including the parameters of plant height, number of tillers, shoot biomass and root biomass. Plant growth is one of the parameters that determine whether the application given has an effect or not. The analysis of rice plant height showed that the application of 2 t/h = Azolla + NPK (T_8) gave the highest results with an average height of 68.6 cm (Table 4). This is in line with research by Thapa and Poudel (2021) who reported that using organic materials will increase the efficiency of anorganic fertilizers. According to Al-Bdairi and Kamal (2021), the application of Azolla significantly affects plant height. The increase may be due to the content of Azolla elements necessary for plant growth and development, which activates the process of cell division and elongation and stimulates vegetative growth, including rice plant height. This is in line with the fact that the availability of nutrients N, P, and K, in addition to organic fertilizers, will spur plant growth. Among the various organic fertilizers, although not significantly different, Azolla showed a higher effect on plant height than other organic material sources of manure and straw compost. While for the number of tillers, the use of Azolla fertilizer + NPK (T_8) had a higher effect than manure and rice straw compost. The application of 2 t/ ha = Azolla + NPK (T_8) had the highest number of tillers with an average value of 18,67. This is because the availability of N, P and K nutrients from organic fertilizer (Azolla) in the maximum vegetative phase thus influences the number of tillers. According to Setiawati *et al*. (2020), the more significant number of tillers can be caused by the availability of more N, which is responsible for cell division and cell elongation.

The results of the measurement of dry biomass produced, each treatment of Azolla 10 t/h (T_7) and Azolla 2 t/h + 90 kg/h compound NPK (T_8) gave an average of 22.55 g and 23.00 g. Meanwhile, root weight gave results with an average of 8.0 g of Azolla 10 t/h (T_7), not significantly different from 2 t/h Azolla + 90 kg/h NPK (T_8) at 7.8. According to Ichsan *et al*. (2017), dry weight illustrates optimal nutrient absorption by plants. In this case, the nitrogen content of Azolla plays a very important role because nitrogen is a determining factor for plant growth and productivity. According to de Anicésio *et al*. (2015), plant dry weight is directly related to nitrogen supply; when nitrogen supply is low, the dry weight will be low, especially in leaves that affect the assimilation and distribution of assimilation to other reproductive organs. The addition of Azolla organic fertilizer showed a positive response to plant height and dry weight in the vegetative phase. Hazmi *et al*. (2020) reported that Azolla supplemented with inorganic fertilizers produces the highest dry weight because plants absorb a lot of nitrogen during the vegetative period. According to Setiawati *et al*. (2020), in the vegetative phase, nutrient sufficiency is very necessary, especially N nutrients, because many physiological and metabolic processes are related to the sufficiency of N nutrients, which is the most important nutrient. Therefore, the availability of N

Table 4. Effect of treatment on Inpari 32 rice growth

No.	Treatment	Plant Height (cm)	Number of tiller/clump	Shoot Biomass (g/clump)	Root Biomass (g/clump)
T_0	Control	56.20^{a}	15.67^{a}	14.89^{a}	6.8^{a}
T_1	90 kg/h	64.13^{bc}	16.00^{a}	15.11^{a}	8.0^{a}
T_2	45 kg/h NPK	63.27^{b}	17.00^{ab}	17.55^{ab}	7.3^{a}
T_3	10 t/h Manure	64.47^{bc}	17.33^{ab}	19.44^{abc}	8.6^{a}
T_4	2 t/h Manure + 90 kg/h NPK	65.13^{bcd}	16.00^{a}	25.88^{d}	15.0^{b}
T_5	10 t/h Rice straw compost	64.20^{bc}	17.67^{ab}	21.00^{bcd}	8.6^{a}
T_6	2 t/h Rice straw compost + 90 kg/h NPK	67.13^{de}	17.33^{ab}	21.89^{bcd}	8.6^{a}
T_7	10 t/h Azolla	65.87^{bcd}	16.00^{a}	22.55^{bcd}	8.0^{a}
T_8	2 t/h Azolla + 90 kg/h NPK	68.60^{e}	18.67^{b}	23.00^{cd}	7.8^{a}

Table 5. Effect of treatments on nutrient uptake of N, P, K

No.	Treatment	Uptake N-Shoot (g/clump)	Uptake P-Shoot (g/ clump)	Uptake K-Shoot (g/ clump)
T_0	Control	0.31^{a}	0.13^{a}	0.15^{a}
T_1	90 kg/h NPK	0.53^{b}	0.20^{a}	0.19^{ab}
T_2	45 kg/h NPK	0.57^{b}	0.23^{ab}	0.22^{bc}
T_3	10 t/h Manure	0.64^{bc}	0.23^{ab}	0.26^{cde}
T_4	2 t/h Manure + 90 kg/d NPK	0.80^{cd}	0.50^{d}	0.28^{def}
T_5	10 t/h Rice straw compost	0.60^{b}	0.36^{c}	0.23^{bcd}
T_6	2 t/h Rice straw compost + 90 kg/h NPK	0.62^{b}	0.32^{bc}	0.27^{cd}
T_7	10 t/h Azolla	0.82^{d}	0.44^{c}	0.34^{f}
T_8	2 t/h Azolla + 90 kg/h NPK	0.65^{bc}	0.35^{c}	0.32^{ef}

nutrients plays an important role in obtaining good growth.

Effect on N, P, and K uptake

The addition of organic fertilizer affects plant nutrient uptake. The uptake of soil nutrients by plants N, P, and K are macronutrients widely absorbed by plants. Azolla can release absorbed minerals through the mineralization process during decomposition. N, P, and other nutrients applied through inorganic sources are quickly released into the media and made available for plant uptake. According Thapa and Poudel, (2021), Azolla biofertilizer increases plant nitrogen recovery by 49-64% and decreases N losses by 26-48%. Durán-Lara *et al*., (2020) reported that the decomposition and mineralization process will release N that plants can absorb. Plants utilize or absorb nitrogen in the form of NO_3^- or NH_4^+, but plants absorb more nitrogen in the form of NO_3^-. According to Moreau *et al*. (2019), the factors affecting N uptake include the amount of nutrients, the amount of soil nitrogen and the physiological conditions of the plant. The analysis of variance shows that the provision of Azolla 10 t/h (T_7) significantly affects nitrogen uptake. Applying 10 t/h Azolla (T_7) gives the nitrogen uptake result of 0.82 g/plant. This shows that using Azolla is very influential on N absorption activities. Applying Azolla in the soil means it contributes to good nitrogen absorption. According to Seleiman *et al*. (2022), adding Azolla can increase nitrogen uptake and efficiency, reducing N losses in rice.

The highest P uptake value was found in the treatment of 2 t/h Manure + 90 kg/t NPK (T_4); the treatment of 10 t/h Azolla (T_7) got the second highest value with a value of 0.50 g/plant (Table 5). The treatment of Azolla was able to compensate for the results of the treatment of organic fertilizers, manure, and straw. According to Püschel *et al*. (2021), the transport of P ions through the soil by diffusion is slower than the transfer across the root cell membrane; therefore, a depletion zone develops around the plant roots. Therefore, P uptake by plant roots depends on P diffusion in the soil solution and soil water content around the roots. The 10 t/h Azolla (T_7) treatment gave the highest value on tissue K uptake of 0.34 g/plant. The treatment showed a significant increase from the control treatment. According to Syarif *et al*. (2013), the provision of Azolla inoculum will increase the content of organic matter in the soil to increase microbial activity that can help release K nutrients bound in the soil. Adding organic

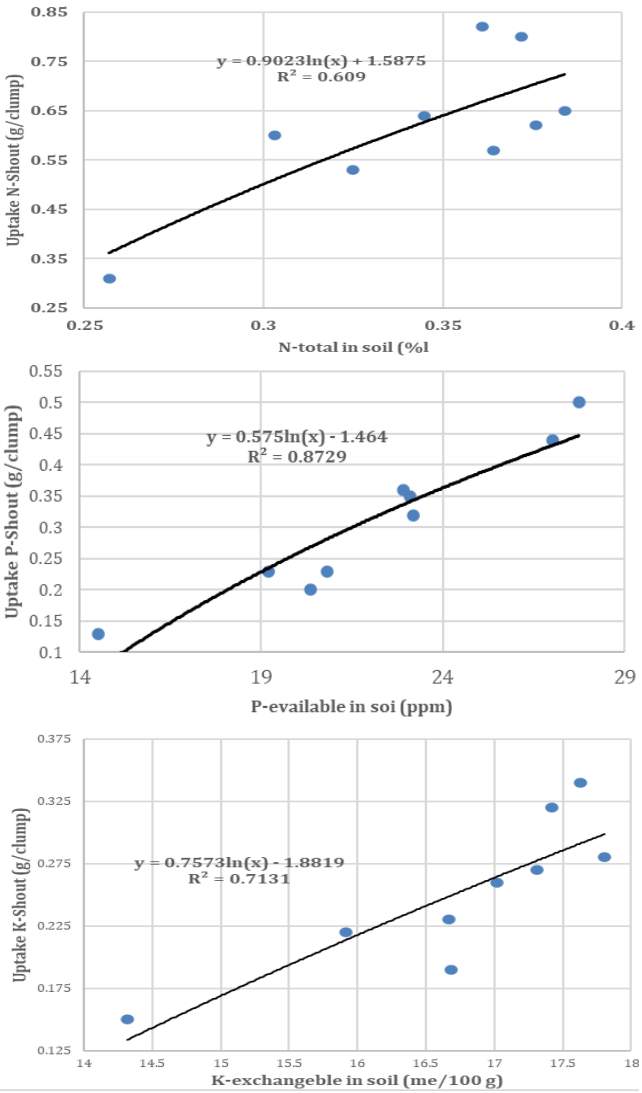

Fig. 1. *Relationship between Availability and Uptake of Nutrients N, P, and K*

potassium fertilizer will be more effective and increase the exchangeable K in the soil.

Relationship between availability and uptake of nutrients N, P, and K

Applying organic fertilizers and NPK fertilizers increases the availability of nutrients N, P, and K. The increased availability of these nutrients positively responds to nutrient uptake. The results of this study show a positive relationship between N, P, and K availability to nutrient uptake. NPK fertilizer will directly increase the nutrients N, P, and K. However, adding organic fertilizer through the mineralization process will release the available NH_4^+ and NO_3^- that plants can absorb. This is evident in Fig. 1, which shows a response to increasing plant N absorption. Angelova *et al*. (2013), In the mineralization of organic matter gradually, in addition to releasing N nutrients, it will also release nutrients PO_4^-, K^+, and other nutrients available to plants so that the increased availability of P and K will increase the absorption of P and K. This is in line with previous research by Suntoro *et al*. (2018) on corn plants, which showed that adding manure, besides increasing the availability of N, P, and K nutrients, also increased their uptake.

Conclusion

In the present study, adding organic matter from manure, straw compost, and Azolla 10 t/h (T_3, T_5 and T_7) showed an increase in soil organic carbon, soil CEC, and soil pH, which was still in the neutral range. The increase in CEC was due to increased negative groups in the soil. Among the organic fertilizers used, Azolla fertilizer increases total N in the soil higher than cow dung and straw compost and will increase the efficiency of NPK fertilizer use. Azolla organic fertilizer and rice straw compost showed increased availability of P and K-available nutrients in the soil. Azolla had the highest effect on P-available among the three organic fertilizers. For the availability of exchangeable K, the use of manure and Azolla affected increasing exchangeable K. Azolla fertilizer, manure, and rice straw compost affect plant growth. Among these three, Azolla fertilizer had the highest effect. The highest impact of Azolla fertilizer varied with NPK fertilizer (T_8) for the number of tillers parameter, and manure fertilizer varied with NPK fertilizer (T_4) on the shoot biomass and root biomass parameters. The highest value of rice plant height was found in the treatment of Azolla 2 t/ha + NPK (T_8). Azola fertilization and straw compost affected the uptake of N, P, and K, and Azolla fertilizer (T_7) had the highest effect. Manure varied with NPK fertilizer (T_4) only showed an increase in P uptake, and rice straw compost showed an increase in K uptake when varied with NPK fertilizer (T_6). A positive relationship existed between N, P, and K nutrient availability and uptake.

Conflict of interest

The authors declare that they have no conflict of interest.

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