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Increasing Nitrogen Fertilizer Efficiency on Wetland Rice by Using Humic Acid

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ABSTRACT

The objective of the research was to study the interaction between dose of humic acid and nitrogen fertilizer on the growth and yield of rice. The experiment was conducted in May until September 2014 in Sukamanah village Cipedes sub-district Tasikmalaya city. A field experiment was done using as split plot design consisted of two factors. The dosage of humic acid were placed as main plot consisted of four levels *i.e.* 0 kg ha^{-1}, 3 kg ha^{-1}, 4 kg ha^{-1}, and 5 kg ha^{-1}; and the rate of N fertilizer, as subplot, consisted of 4 levels *i.e.*0 kg N ha^{-1}, 45 kg N ha^{-1}, 67.5 kg N ha^{-1}, and 90 kg N ha^{-1}. The variables observed were: (a) the levels of soil organic C before and after treatment, (b) the levels of crop N, and (c) the components of growth and yield. Nitrogen fertilizer efficiency was expressed in terms of agronomic efficiency of nitrogen (AEN). The results showed that the growth and yield of rice given humic acid was higher than that without humi cacid. The increasing dose of humic acid *i.e.* 3 kg ha^{-1}, 4 kg ha^{-1}, and 5 kg ha^{-1} did not have significant effect. A higher response on growth and grain yield was shown at the dose of humic acid 3 kg ha^{-1}. Nitrogen fertilizer gave significant effect on all growth variables and yield of rice. The higher the level of nitrogen fertilizer up to a certain level (*i.e.* 67.5 kg N ha^{-1} or equals to 150 kg Urea ha^{-1}), the higher would be the effect on all growth variables and yield. The increase in weight of grain ha^{-1} due to the increased level of nitrogen fertilizer compared to those without nitrogen fertilizer (control) were respectively 58.05% at 45 kgha^{-1} N, 150.54% at 67.5 kg ha^{-1} N, and 168.13% at 90 kg ha^{-1} N. Humic acid increased the efficiency of N fertilizer. The most efficient dose of N fertilizer was 67 kg ha^{-1}, equal to 150 kg ha^{-1} combined with humic acid 3 kg ha^{-1}.

Keywords: Humic acid, nitrogen fertilizer, nutrient efficiency, wetland rice

INTRODUCTION

Effort to increase rice production is facing with various constraints, among others, are low of soil organic matter and inefficiency use of inorganic nitrogen fertilizer. Soil organic matter continues to decrease because farmers use chemical fertilizers continuously without the addition of organic matter (Suwardi 2009). As a result, soil becomes more acid and hard and the lives of most soil microorganisms are retarded. In such conditions, soil becomes more irresponsive to fertilization and it is difficult to continue increasing the rice production (leveling off) (Abdurrahman *et al.* 2011).

According to Saraswati *et al.* (2004), organic matter plays important role as biological buffer so that soil can provide balanced amounts of nutrients for plants. Soil with poor organic matter will decrease its buffering capacity, so that the efficiency of inorganic fertilizers, especially nitrogen fertilizer, is reduced and disappeared from the rizhosphere. The integrated soil nutrient management is required to optimizethe use of organic and inorganic fertilizers, in that the provision of inorganic fertilizer should be in combination with organic fertilizer.

Nitrogen is essential for plant growth. However, nitrogen is leached from the soil in the form of nitrate, evaporates into the air in the form of ammonia gas, or change in shape which will be difficult to absorb by plant (Suwardi 2009). Therefore, it is necessary to improve the efficiency of nitrogen fertilizer through integrated plant nutrient management system by applying a balanced fertilizer, which minimizes the use of inorganic fertilizer and maximize the use of organic material/organic fertilizer.

Recommendation to use organic fertilizer in rice is not easy to implement. Perception that organic fertilizers is cheap difficult to prove; despite its relatively low in unit price but it is voluminous in application, so it becomes more expensive,and it is not always available. The problem can be overcome by using "accelerator" humic acid.

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It has been known that the source of natural organic matter in fertile soil derived from humic substances that are usually accumulated at the top of soil layer. The main active substance in humus that contribute to soil fertility is humic and fulvic acid. These compounds are organic substances, stable and as the end result of the decomposition of organic matter (Goenadi 2009). Some important properties of humic acid associated with its role in improving soil conditions and plant growth are that it has high cation exchange capacity (CEC) with high water holding capacity and has good absorption properties, as a complexing agent, and the ability to bind pollutants in soil (Wardani 2002). With these properties humic acid can be used to improve soil fertility.

The use of humic acid as a substitute for part or all organic fertilizer (compost or manure) would be an alternative solution to answer the recommendation to use balanced fertilization to increase the productivity and quality of crops; to minimize the use of nitrogen fertilizers to reduce its impact on the environment; and to gain some economic benefits.

The objectives of the study was to find out the role of humic acid as substitute for organic fertilizer to reduce or minimize the use of nitrogen fertilizers, to increase the growth and yield of rice, and to find out the interaction effect between the dose of humic acid and dose of nitrogen fertilizer on the soil organic-C levels, the nutrient uptake, growth, and yield of rice.

MATERIALS AND METHODS

Study Sites

The field experiment was carried out in Sukamanah village,Cipedessub-district, Tasikmalaya city on May to September 2014. Humic acid ("HUMIKA") is made of mineral Leonardite. Rice seed Inpari 19 (Sidenuk) was used as an indicator plant; (4) chemicals for the chemical analysis of the soil and plants.

Experimental Setup

The experiment used a split plot design with two factors. The first factor was the dose of humic acid, as the main plot, consisted of 4 levels, namely: H_0(without humic acid as control), H_1(3 kg ha^{-1} humic acid), H_2 (4 kg ha^{-1} humic acid), H_3(5 kg ha^{-1} humic acid). The second factor was the dose of N fertilizer, as subplots, consisted of 4 levels, namely: N_0 (0 kg ha^{-1} N as control), N_1 (45 kg ha^{-1} N), N_2 (67.5 kgha^{-1} N), N_3 (90 kg ha^{-1} N), and each treatment was repeated 3 times. The integrated crop management model (PPT) of rice cultivation was used in this experiment (Balai Penelitian Tanaman Padi 2011).

Treatmeant Appliation and Observation

Humic acid (500 L ha^{-1}) was applied twice *i.e*. half the dose of each treatment was given first as basal fertilizer at planting time; it was dissolved in water, stirred, and sprayed onto the soil surface evenly, then the remaining half dose was applied in mixture with urea in subsequent fertilization (20 days after planting).

The response variables of the experiment were: components of growth and yield of rice (plant height, number of tillers/hill, panicle number/clump, the percentage of empty grains, weight of 1000 grains, weight of dry harvest grain, and the weight of dry milled grain (MPD). The efficieny of N fertilizer was expressed in terms of agronomic efficiency (AEN) by the following formula:

$$AEN = (HGN_1 - HG\ N_0) / N_1$$

where:
AEN : Agronomic Efficiency of N,
HGN_1 : Grain yield on N treatment,
HGN_0 : Grain yield on treatment without N,
N_1 : N doses used.

The data were analyzed statistically with split plot design double variable analysis of variance, followed by Duncan's Multiple Range Test at the significance level 0.05. The analysis of the response curve is used to determine the optimum dose of humic acid at each dose of fertilizer N.

RESULTS AND DISCUSSION

Plant Height

N fertilizer affected plant height dependent on dose of humic acid (Table 1). Increasing dose of N fertilizer significant by increased the plant height at without humic acid treatment. In the humic acid treatment, without N fertilizer the highest dose of humic acid gave the higher rice crops. Whereas, various levels of N fertilizer (45 kg ha^{-1}, 67.5 kg ha^{-1}, and 90 kg ha^{-1}) did not show significant effect on plant higher at humic acid dose of 3 kg ha^{-1}, 4 kg ha^{-1} and 5 kg ha^{-1}.

Table 1 shows that plant height treated with humic acid was higher than without humic acid. It was assumed that it was due to the existence of active subtances that promoted the plant growth. Humic acid plays a role not only as soil conditioner

Table 1. Plant height of rice in the primordial phase (48 days after planting) at various doses of humic acid and N fertilizer rate.

Humic Acid (kg ha^{-1})	Nitrogen fertilizer (kg ha^{-1})			
	0	45	67.5	90
	---------------------------- cm	----------------------------		
0	54.70 a A	61.30 a B	68.20 a C	71.77 a D
3	55.17 a A	68.03 b B	72.17 ab BC	75.05 ab C
4	58.83 a A	73.73 c B	72.13 ab B	76.12 ab B
5	65.33 b A	74.13 c B	75.53 b B	76.77 b B

Description: Figures followed with the same lowercase (vertical direction) and uppercase (horizontal direction) are not significantly different according to Duncan's multiple range test at 5% significance level.

but also as plant growth promoter (PT Advance Global Greentech 2010). Humic acid acts as plant growth hormone like auxin and sitokinine. The same response was reported by Suwardi (2009), that humic acid contains growth promoter substance that increased the growth of plant roots and the height of plant, accordingly.

In addition, based on the nature of the exchange cation, the acid can bind and temporarily store the nutrients in the soil and then release back into the soil when the plants needed it. According to Maulana *et al.* (2008), the humic acid has a high CEC, humic acid with clay plays an important role on a number of chemical activities of soil. The use of acid can improve soil fertility through increased soil CEC, thereby increasing the nutrient availability to plants.

Tillers Number

The dose of humic acid and dose of N fertilizer showed significant effect on the number of tillers per hill (Table 2). Table 2 shows an increase in the number of tillers per hill with the increasing level of humic acid compared to those without humic acid. But the increased use of humic acids of 4 kg ha^{-1} to 5 kg ha^{-1} effect is not real. This means that the provision of humic acids which have a high CEC and pH and has a role in stimulating the growth of plants is only needed for up to 4 kg ha^{-1}.

The number of tillers per hill of those fertilized with N fertilizer was more than control (without N fertilizer), the higher the N fertilizer used the higher the number of tillers formed. The N nutrient available in the soil is absorbed by the plant increase the vegetative growth of plants in the formation of new shoots or tillers (Gardner *et al.* 2008).

As well as the plant height, the data in Table 2 indicates that humic acid treatment at different nitrogen rate produce an average number of seedlings more than without humic acid treatment. This is presumably because the humic acid can increase the availability of nitrogen fertilizer for plants. Suwardi (2009), the humic acid slow release

Table 2. Number of tillers per hill at primordial phase (48 days after planting) at varion doses of humic acid and N fertilizer.

Humic Acid (kg ha^{-1})	Nitrogen Fertilizer (kg ha^{-1})				Average
	0	45	67.5	90	
	---------------------	Tiler per hill	------------------------		
0	11.03	19.27	21.33	24.50	19.03 a
3	16.27	21.13	22.2	24.73	21.08 b
4	16.47	22.40	31.03	33.90	25.95 c
5	16.60	25.07	31.73	33.37	26.69 c
Average	15.09 A	21.97 B	26.58 C	29.13 D	

Description: Figures followed with the same lowercase (vertical direction) and uppercase (horizontal direction) are not significantly different according to Duncan's multiple range test at 5% significance level.

the nitrogen fertilizer, so the plants will get a chance to absorb more nitrogen.

The role of nitrogen is associated with photosynthetic activity, thus directly or indirectly nitrogen is very important in the metabolism and respiration (Abdurrahman *et al*. 2011). Improvement in the absorption of nitrogen will support the metabolism so that the plants will be activated to form shoots. Establishment of tillers, plant height is influenced by the availability of nitrogen (Suwardi 2009).

Panicles Number

The statistical analyisis showed that there was no interaction between the dose of humic acid and the dose of N fertilizer on the number of panicles per hill. However, independently, humic acid and N fertilizer gave significant effect on the number of panicles per hill (Table 3).

Table 3 shows that the average number of panicles per hill in the treatment of humic acid is more than without humic acid, but an increasing number of panicles per hill due to an increase in the level of provision of humic acid of 3 kg ha^{-1} to 5 kg ha^{-1} did not have significant effect. This is understandable because the number of tillers per hill at vegetative stage in rice plants in the humic acids treatment were more compared to without humic acid treatment. The number of tillers per hill in the vegetative phase has an important role in its contribution to the number of panicles per hill generated, as it seems almost all tillers produces panicles. As described above, the humic acid is able to increase the availability and absorption of plant nutrients through their ability to bind, adsorb and exchange of nutrients and water needed by the plant for the enzymatic process and preparation of tissue in sufficient quantities (Abdurrahman *et al*. 2011). Slow release nitrogen causes the presence of nitrogen in the soil longer and fertilization more efficient (Suwardi 2009).

Grain Weight

Table 4 shows weight of milled rice (paddy) per hectare (moisture content 14%) due to various doses of humic acid and N fertilizer. Weight of milled rice per hectare did not affected by interaction between humic acid and N fertilization. But independently using humic acid and N fertilization at various doses showed a significant effect on the weight of dry milled grain.

In general, the average weight of dry milled grain was higher at various level of humic acids than

Table 3. Number of panicles per hill at various doses of humic acid and N fertilizer.

Humic acid (kg ha^{-1})	Nitrogen fertilizer (kg ha^{-1}) 0	45	67.5	90	Average
	-----------------------	panicles per hill	----------------------		
0	9.23	15.03	19.43	24.37	17.02 a
3	14.6	22.63	26.13	27.57	22.73 b
4	16.63	24.27	26.47	25.93	23.33 b
5	16.53	25.33	25.67	25.97	23.38 b
Average	14.25 A	21.82 B	24.43 C	25.96 C	

Description: figures followed the same lowercase and uppercase vertical horizontal direction are not significantly different according to Duncan's multiple range test at 5% significance level.

Table 4. Weight of milled rice at various doses of humic acid nitrogen fertilizer.

Humic acid (kg ha^{-1})	Nitrogen fertilizer (kg ha^{-1}) 0	45	67.5	90	Average
	----------------------	Mg ha^{-1}	---------------------------		
0	1.54	3.01	4.94	5.35	3.71 a
3	2.00	3.74	5.53	5.82	4.28 b
4	2.33	2.86	4.74	5.48	3.85 b
5	2.45	3.55	5.64	5.67	4.33 b
Average	2.08 A	3.29 B	5.22 C	5.58 C	

Description: Figures followed the same lowercase and uppercase vertical horizontal direction are not significantly different according to Duncant multiple range test at 5% significance level.

without humic acid (control), but the application of humic acid 3 kg ha^{-1}, 4 kg ha^{-1}, 5 kg ha^{-1}each other did not show a significant effect. The increase in weight of grain due to an increase in the level of provision of humic acid as compared to the control (without humic acid) by an average of 15.18%, 13.80% and 16.60% for 3, 4, 5 kg ha^{-1} of humic acid, respectively.

This shows that the humic acid that has high CEC and pH and also has a role in stimulating the plant growth was only required as much as 3 kg ha^{-1}. The use of humic acid to 5 kg ha^{-1} is thought to bind the N in the soil stronger, so the availability of N when plants need it was less. This may be related to the ability of humic acids to bind the N more tightly at high doses. Research results of Suwardi (2009), the addition of humic acid on urea can slow the changes of N-ammonium into nitrate-N. The higher the levels of humic acid, the more the number of N-ammonium existed in the soil.

The increase in weight of grain per hectare due to an increase in the level of N fertilizer compared to the control (without N fertilizer), an increase in the level of fertilizer up to 67.5 kg ha^{-1} N, equal 150 kg ha^{-1} urea, will increase grain weight. The effect of increasing N fertilization 67.5 kg ha^{-1} to 90 kg ha^{-1}was not significant. The increase in weight of grain per hectare due to the increased level of N fertilization compared to control was in the average of 58.05%, 150.54% and 168.13% for 45, 67.5 and 90 kg ha^{-1} N, respectively.

The results are consistent with Abdurrahman *et al.* (2011), that a healthy plant growth is reflected by optimal plant nutrient status. Optimum and critical nutrient concentrations in rice crops depending on climatic conditions and crop varieties. It mean that a particular nutrient uptake by plants is not only determined by the nutrient status in the soil not fertilizer supplied. Other soil conditions that influence the growth and yield are C-organic and CEC. Humic acid application increased C-organic and soil CEC, that the nutrients provided in the form of fertilizer will be more effective and efficient. Therefore, fertilizer required is also relatively less. The available nutrients is affected by soil properties, namely the physical, chemical and biological soil properties. These properties interact in conditioning the soil.

Nitrogen Fertilizer Efficiency

The efficiency of fertilization is the addition of yield obtained from unit fertilizer added in a particular soil and climate conditions. Based on the calculations using the equations; EAN = (Ni-HGN0 HG)/Ni, the efficiency of fertilizer N in rice plants are presented in Figure 1.

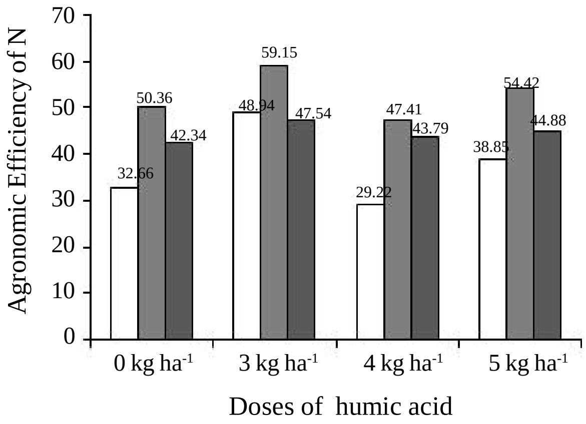

Figure 1. Efficiency of nitrogen fertilizer on various doses of humic acid. □: 45 kg ha^{-1} N, ■: 67.5 kg ha^{-1} N, ■: 90 kg ha^{-1} N.

Grain yield obtained from each unit of N fertilizer on the treatment of humic acid is higher than those without humic acid. It shows that the dose of nutrient N applied on dose of humic acid was more efficient. The application of humic acids increased the efficiency of N fertilization with the highest value obtained in the dose of 3 kg ha^{-1} humic acid at the dose of 67.5 kg ha^{-1} N fertilizer *i.e.* 59.15.

The figure above shows that the use of humic acid can improve agronomic efficiency in the use of N fertilizer in rice plants, because humic acid can slower the release of N fertilizer so that the plants more efficient in the use of nitrogen. Suwardi (2009), with the slower release of nitrogen into nitrate, fertilizer loss caused by evaporation and leaching is smaller, so that the rice plants have a chance to absorb nitrogen more. It means that humic acid can improve the efficiency of N fertilizer.

CONCLUSIONS

The growth and yield of rice given humic acid was higher than those without humic acid. The highest response on growth and grain yield obtained at the application of 3 kg ha^{-1}humic acid. The nitrogen fertilizer gave effect on all variables of growth and yield of rice. The increase in weight of grain per hectare was due to the increased level of nitrogen fertilizer compared to those without nitrogen fertilizer (control) was averaged 58.05%, 150.54% and 168, 13% for 45, 67.5, and 90 kg ha^{-1} N, respectively. Humic acid increases the efficiency of nitrogen fertilizer. The most efficient dose of nitrogen fertilization was 67 kg ha^{-1} N or equals to 150 kg ha^{-1} with the application of 3 kg ha^{-1} humic acid.

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