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DETERMINATION OF UREA-HUMIC ACID DOSAGE OF VERTISOLS ON THE GROWTH AND PRODUCTION OF RICE

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ABSTRACT

The main problem of the use of N fertilizer in paddy soil Vertisols is the low efficiency. Urea-humic acid applications at certain dosage are believed to increase rice growth and production. This study was aimed to examine the effect of urea and urea-humic acid to the amount and form of N-available, N uptake, plant growth, and the production of rice. Five dosage levels of urea-humic acid were applied for rice on Vertisols. Results of the research showed that the urea-humic acid fertilizer could increase the content of N-NH_4^+ soil at 28 days and N-NO_3^- soil at 42 days. The urea-humic acid could improve plant height, number of tillers, and total dry weight. The highest rice production is achieved by 100% humic acid-urea, especially on parameters of dry weight effectively harvested and effectively milled, with 5.56 tons and 4.61 tons per hectare respectively. Correlation between soil N-NO_3^- level with soil N-NH_4^+ level was significant at p = 0.05 (r = 0.871). Efficiency of urea-humic acid fertilizer at 100% recommended dosage (200 kg urea-humic acid) to the dry weight of effectively harvested crop with dry weight of effectively milled crop was 22% compared to the recommended urea fertilizer (200 kg ha^{-1}).

Keywords: N-NH_4^+, N-NO_3^-, plant growth, the production of rice, urea-humic acid

INTRODUCTION

Nitrogen is essential for the growth of rice. This element is easily leached from the soil in the form of nitrate (N-NO_3^-), and it is evaporated into the air in the form of ammonia gas (NH_3) or remained in the soil in a form that can not be absorbed by plants. Application of humic acid to soil can improve soil fertility, and impacts on plant growth and production. It has been reported in cowpea (Azarpour *et al*., 2011), chickpea (Kaya *et al*., 2005), potato (Mahmoud and Hafez, 2010), bean (Salwa, 2011), wheat (Katkat *et al*., 2009), and juwawut (Saruhan *et al*., 2011).

Humic acid will be economical when applied through the soil with concentrations of less than 0.2%, and applied through the leaves with a concentration of less than 0.1% (Khaled and Fawy, 2011). Katkat *et al*. (2009) did the application of humic acid Leonardite through the leaves (0.1%) and via the soil (0.1%); the results showed an increase in dry weight and uptake of N, P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn in wheat. Saruhan *et al*. (2011) reported that the plant height, weight of 1,000 seeds, and maximum protein concentration obtained from the application of humic 100% through the leaves, is different when compared with the application through the soil mixed with millet seed applications. Azarpour *et al*. (2011) found application 50 mg L^{-1} humic acid through the leaves in cowpea can produce 1,486 kg ha^{-1}, whereas the application of 45 kg ha^{-1} urea produced 1,566 kg ha^{-1}. Kaya *et al*. (2005) found that the application of humic acid and Zn before sowing affects the activation of the growth of the roots and the top of the plant, thereby increasing the production yield of beans. Pettit (2004) reported that with the application of humic, then the need for fertilizer N, P and K can be reduced. Researchers from the University of North Dakota combine Leonardite with NPK fertilizer could increase N uptake by 95% of potato production and 23% of sugar beet production (Mahmoud and

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Hafez, 2010). This proves that the application of humic acid in the soil can affect the quality of crops through the increase of fertilizer efficiency (Zimmer, 2011).

Humic acid has several functions for soil and crops. Humic acid can increase the permeability of cell membranes of plants, intensify plant enzyme systems, and make plants more resistant to diseases (Zimmer, 2011). Nuryani *et al*. (2007) reported that the engineering urea-humic acid derived from Palangkaraya and Rawapening peat on Vertisol and Entisol, can increase the uptake of N and increase the growth of sugarcane.

In the vertisol paddy fields with 2:1 type clay minerals (montmorillonite), N-NH_4^+ fixation by clay minerals can lead to low availability of nitrogen to plants. Coating urea with humic acids causes slow release of N (NH_4^+ and NO_3^-). The slow release of N (NH_4^+ and NO_3^-) of urea-humic acid in line with the rate of plant growth causes nitrogen losses reduced through volatilization and leaching. The available nitrogen can then be absorbed by plant roots as needed at each stage of growth. Thus, nitrogen loss can be prevented and, the efficiency of nitrogen application on growth can ultimately affect production of rice.

Studies on the release of N (NH_4^+ and NO_3^-) from urea-humic acid have been published previously (Suntari *et al.,* 2013a), as well as studies on the effect of flooding on soil chemical properties and N (NH_4^+ and NO_3^-) (Suntari *et al.,* 2013b). On the other hand, the influence of the availability of N (NH_4^+ and NO_3^-) released by urea-humic acid on Vertisols for plant growth and rice production is still unknown. Therefore, the purpose of this research was to examine the effect of application of urea and urea-humic acid to the number of N-NH_4^+ and N-NO_3^- in soil, N uptake, plant growth, and the production of rice.

MATERIALS AND METHODS

Fieldwork was conducted from October 2011 to April 2012 at the Experimental Station of the Research Center for Legume and Tuber Crop, Ngale, Ngawi, East Java, Indonesia, during the rainy season and analysis of soil and plant samples were taken place in the Soil Chemistry Laboratory, Faculty of Agriculture, Brawijaya University, Malang. Fertilizers used were: urea, SP36, KCl and urea-humic acid 260 ppm. Seed supply was Inpari 6 Jete. The type of soil used was Vertisol. Urea-humic acid (260 ppm) was processed by mixing urea with potassium humic acid obtained from Leonardite sediment originating from Gippland in Victoria, Australia. The urea used was 46% N which was produced by the fertilizer company in Bontang, East of Kalimantan.

Given dosage of fertilizer was 200 kg urea ha^{-1} (100% recommended dosage = U), SP36 200 kg ha^{-1}, and KCl 200 kg ha^{-1}. Urea fertilization was given twice, the first-half at planting and the second-half of the dosage when the plant was 21 dap whereas KCl fertilization and SP36 was given at the time of planting. Urea-humic acid (UH) was given at the time of planting of seedlings in experimental plots, with UH1 treatment (75%), UH2 (100%), UH3 (125%), UH4 (150%), and UH5 (200%) as recommended dosages, and each were 150 kg ha^{-1}, 200 kg ha^{-1}, 250 kg ha^{-1}, 300 kg ha^{-1} and 400 kg ha^{-1} urea-humic acid respectively.

Observation of the growth components included plant height, number of tillers, number of leaves, plant dry weight total, and number of panicles. Observation of yield components was weight of milled rice in t ha^{-1}. Soil analysis was performed at weeks 2, 4, 6 and 8. Soil analysis was conducted to determine the content of N-NH_4^+ and N-NO_3^-, while the analysis of the plant included: total-N, N-NH_4^+ and N-NO_3^- using Kjeldahl (Hidayat, 1978).

The data obtained were statistically tested using ANOVA with F test RBD (5% level) to see the differences between the treatment effect. If there were significant differences among treatments then followed by Duncan's test at 5% level. Correlation tests were used to determine the relationship between the parameters, the levels of N-NH_4^+ and N-NO_3^- in soil and plants, N uptake total, component growths and yield components of rice. Data analysis used SPSS 16.

RESULTS AND DISCUSSION

Effect of Urea-Humic Acid Dosage on the Availability of N-NH_4^+ and N-NO_3^- in Soil

Application of different dosages of urea-humic acid affects the availability of NH_4^+ and N-NO_3^- on Vertisols rice field in Ngale, Ngawi (Table 1).

Urea-humic acid could significantly reduce the availability of NH_4^+ in soil, from 43.786 mg kg^{-1} on U (100% urea) to 2.260 mg kg^{-1} in the soils that was given urea-humic acid 200% (UH5). At 14 dap and 42 dap, availability of NH_4^+ was not significantly different between treatments. It is possible that at 14 dap the availability of NH_4^+ is affected by urea hydrolysis. While at 42 dap, although it has been used for rice vegetative-growth, NH_4^+ is still available in the soil.

Humic acid-urea can significantly improve the availability of N-NO_3. Statistical test results (Table 1) at 14 dap shows that the availability of N-NO_3 at 100% urea (U) is 3.295 mg kg^{-1}, which shows an increase to 19.179 mg kg^{-1} in the land given 125% humic acid-urea (UH3). Further increases in urea-humic acid does not give a significant difference to the application of urea only.

On the other hand, at 42 dap, N-NO_3 decreased significantly as a result of different treatment dosage of urea-humic acid, in which the higher dosage given, the lower availability of N-NO_3. Meanwhile, the highest availability of N-NO_3 was in 10.349 mg kg^{-1} urea treatment, and decreased to the lowest level in the treatment of UH3 (125% humic acid-urea). But this result was equal to the soil with UH5 treatment (200% humic acid-urea).

It can be concluded that urea-humic acid was able to provide NH_4^+ and N-NO_3^- until 42 dap and can be used for maximum vegetative growth. The different results obtained from the findings of Medhi and De Datta (1996) which showed that the N uptake of rice crop was higher when using urea fertilizer treatment compared to treatment with organic fertilizers Sesbania Rostrata at 30 dap, 45 dap and at harvesting time.

The Effect of Urea-Humic acid Dosage on Rice Growth

The urea-humic acid treatment leads to the improvement of soil chemical properties such as increased of pH, NH_4^+ and N-NO_3^-. Nevertheless, the results of statistical tests (Table 2) showed that urea-humic acid did not significantly increase the plant height in paddy soil Vertisols, Ngale, Ngawi. Significant effect was found only when the rice crop was at 42 days. At the age of 42 dap, 75% urea-humic acid treatment (UH1) was the shortest (71.33 cm), and it was significantly different with treatment of urea only (85.83 cm) and 200% urea-humic acid (UH5) with average height of 87.33 cm.

Urea-humic acid with the highest dosage did not differ from treatment with 100% recommended dosage of urea (U). Although not significantly different, when dosage of humic acid-urea increased, it tends to be an increase in plant height at 14 dap, 28 dap and 56 dap. This is presumably because humic compounds can increase the cell permeability and increase growth hormone that finally can promote plant growth (Goenadi, 1999).

Table 1. The effect of urea-humic acid dosages on the availability of $NH_4^+$and N-NO_3^-

Treatment	Soil N-NH_4 (mg kg^{-1})			Soil N-NO_3 (mg kg^{-1})		
	14 dap	28 dap	42 dap	14 dap	28 dap	42 dap
U	13.234	43.786 b	3.767	3.295 a	25.926	10.349 c
UH1	60.847	10.388 a	3.307	9.901 abc	22.249	8.812 bc
UH2	32.286	5.905 a	3.416	13.396 bc	24.526	5.917 abc
UH3	30.111	6.620 a	1.960	19.179 c	12.574	2.188 a
UH4	27.068	4.097 a	2.203	6.984 ab	14.862	2.871 ab
UH5	27.670	2.260 a	1.081	10.284 abc	5.420	2.741 a

Remarks: * Numbers with the same letter in the same column are not significantly different at 5% level of Duncan's test; ** dap = day after planting

Statistical test results (Table 3) showed that the effect of urea-humic acid was only found at 28 dap and 56 dap. In particular, at the age of 14 dap and 42 dap urea-humic acid treatments did not give significant effect on the number of tillers. At the age of 28 dap and 56 dap, urea was not significantly different from urea-humic acid. The only difference observed in urea-humic acid dosages was the number of tillers which tended to increase with the increasing dosages of urea-humic acid. This is probably due to the availability of sufficient N required for vegetative growth.

Statistical test results (Table 4) showed that there was no significant effect of the application of urea-humic acid on stover dry weight. However there is an increasing trend of stover dry weight with increasing urea-humic acid applications. This is due to the positive correlation between stover dry weight during the vegetative age with tiller number (r = 0.806), number of leaves (r = 0.417), and plant height (r = 0.337).

The Effect of Urea-Humic Acid Dosages on Rice Production

The application of various doses of humic acid-urea improve plant growth, so that the production of rice in paddy soil Vertisols also increased. Statistical analysis showed that the application of urea-humic acid could dramatically increase the dry grain harvest weight (g plot^{-1}), dry grain milled weight (g plot^{-1}), effective dry grain harvest weight (t ha^{-1}), and effective dry grain milled weight (t ha^{-1}) (Table 5). The highest number of panicles (6.33) were achieved in the application of urea-humic acid 100% (UH2). Higher dosages (UH5 = 200% urea-humic acid) produced fewer number of panicles. This suggests that UH2 treatment is more effective than the others.

Table 2. The effect of urea-humic acid dosages on plant height

Treatment	Plant height (cm)			
	14 dap	28 dap	42 dap	56 dap
U	33.17	62.17	85.83 bc	91.17
UH1	36.00	58.33	71.33 a	89.83
UH2	35.50	60.67	76.00 ab	89.83
UH3	36.17	57.67	82.00 bc	95.00
UH4	38.00	63.67	80.33 abc	93.50
UH5	37.17	63.83	87.33 c	92.67

Remarks: * Numbers with the same letter in the same column are not significantly different at 5% level of Duncan's test; ** dap = day after planting

Table 3. The effect of urea-humic acid dosages on numbers of tillers

Treatment	Numbers of tillers			
	14 dap	28 dap	42 dap	56 dap
U	4.33	34.33 c	31.67	22.33 d
UH1	5.00	25.33 a	25.00	19.67 bcd
UH2	6.67	33.00 bc	27.00	16.33 a
UH3	5.67	26.33 ab	27.33	19.00 abc
UH4	6.33	28.67 abc	30.33	21.67 cd
UH5	6.00	34.33 c	33.67	20.00 cd

Remarks: * Numbers with the same letter in the same column are not significantly different at 5% level of Duncan's test; ** dap = day after planting

Table 4. The effect of urea-humic acid dosages on oven dried weight of stover

Treatment	Oven Dried Weight of stover (g)			
	14 dap	28 dap	42 dap	56 dap
U	0.92	17.57	41.09	61.44
UH1	0.96	14.11	29.23	59.97
UH2	1.18	18.93	33.40	52.48
UH3	1.12	14.45	31.67	56.23
UH4	1.10	17.13	35.48	70.36
UH5	1.08	21.86	44.15	63.25

Remarks: * Numbers with the same letter in the same column are not significantly different at 5% level of Duncan's test; ** dap = day after planting

Table 5. The effect of urea-humic acid dosages on total number of panicles, dry grain harvest and milled weight

Treatment	Number of panicles	Dry harvest ($g\ plot^{-1}$)	Dry milled ($g\ plot^{-1}$)	Effective dry harvest ($t\ ha^{-1}$)	Effective dry milled ($t\ ha^{-1}$)
U	5.67	2.605.00 a	2.158.66 a	4.558 a	3.777 a
UH1	6.00	2.339.33 a	1.942.33 a	4.094 a	3.399 a
UH2	6.33	3.178.00 b	2.635.00 b	5.561 b	4.611 b
UH3	5.67	2.439.00 a	2.053.83 a	4.268 a	3.591 a
UH4	4.67	2.657.00 ab	2.206.50 a	4.702 ab	3.861 a
UH5	5.33	2.784.66 ab	2.307.00 ab	4.739 ab	4.037 ab

Remarks: * Numbers with the same letter in the same column are not significantly different at 5% level of Duncan's test

Application of urea-humic acid UH2 (100% urea-humic acid) resulted the highest harvested of dry grain weight, dry grain milled weight, effective dry grain weight, and effective weight of milled dry grain compared to other applications of urea and urea-humic acid. The highest dry weight in UH2 is in accordance with the highest number of panicles that was also obtained in the same treatment. Effective weight of the harvested dry grain was 87.5% of the dry grain weight ha^{-1}at the harvest time, and effective weight of the milled dry grain was 87.5% of the dry grain weight after drying process under the sun for 2 days.

Highest yields were obtained with UH2 treatment (100% urea-humic acid) and they were significantly different from the treatment of U (100% urea). This may be caused by the benefits of humic acid that covers the urea from the chemical and biological properties of soil. Chemically, humic acid has a high CEC that is capable of controlling the release of plant nutrients. On the other hand, the influence of inundation is may be able to raise the pH, number of tillers and number of panicles per clump, and increase dry grain weight, Arsana *et al*. (2003). Purakayastha *et al*. (1997) showed that the high CEC Vertisols can reduce the loss of NH_3 from the soil. Although according to Narteh and Sahrawat (2000) N-NH_4^+content is not significantly correlated to CEC and clay content of the soil, however the texture with the amount of clay at 80% is likely able to fixate N-NH_4^+ released by urea-humic acid fertilizer. As shown by Tan (1991), the size of the NH_4^+ will fit with clay octahedral holes measuring 1.4 Å. On the other hand, the amount of N-NH_4^+ can be lost in the oxidation layer on top of waterlogged soil or absorbed by plants. Furthermore, according to Hardjowigeno and Rayes (2005), N also can be lost in the form of nitrate leached to the reduction layer, so it can undergo denitrification to N_2O and N_2. This happens because the optimum temperature for nitrification is between 27-32°C, while the maximum temperature at the location of the study was 33-34°C. Li *et al*. (2003) suggest that the mineralization of N-organic only about 4 up to 9.4% and a temperature between 25-35°C.

The highest dry milled weight obtained with UH2 treatment (100% urea-humic acid) with 4.611 t ha^{-1} was higher than the U treatment (100% urea) with 3.777 t ha^{-1}. The highest effective weight of harvested dry grain was obtained also with UH2 (100% urea-humic acid) with 5.61 t ha^{-1}, while the U treatment (100% urea) was only 4.558 t ha^{-1}. This showed that there had been 22.00% increase in the effective weight of harvested dry grain and 22.08% increase in the effective weight of dry milled grain. This effective weight of harvested dry grain result is still higher than that obtained by Sarwar *et al*. (2007) in Pakistan who get the highest rice yield of 3.94 t ha^{-1} by using 24 t ha^{-1} compost fertilizer + recommended NPK fertilizer (100-70-70 kg ha^{-1}). This suggests that urea-humic acid UH2 treatment has qualified the requirement of the efficiency of the use of N fertilizerin accordance with its role, Pettit (2004) and Zimmer (2011).

The Effect of Urea-Humic acid Dosages on Plant's N Uptake

Application of urea-humic acid had a very significant effect on the level of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ at 56 dap, but it had no significant effect on plant's total of N content. Total of N uptake is influenced by the total of N concentration and dry weight of plant at 56 dap.

The highest concentration of $N\text{-}NH_4^+$ is in UH2 treatment (100% urea-humic acid), while the highest levels of $N\text{-}NO_3^-$ is in UH3 treatment (125% urea-humic acid). Urea-humic acid treatment on other dosages did not differ by treatment with urea only. Uptake of nitrogen by rice crops at 56 dap played a role in the reduction of the content of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ in soil at 42 dap, whereas the high dosage of urea-humic acid was likely to reduce the availability of $N\text{-}NH_4^+$ at 42 dap and it very significantly reduced levels $N\text{-}NO_3^-$ in the soil at 42 dap (Table 6). It also suggested that the higher dosages of urea-humic acid given, the more N would be absorbed by plants for rice vegetative growth.

The possibility of losing N from paddy soils resulted treatments with a different dosages range of urea-humic acid which did not significantly affect the total of N uptake at 56 dap. N uptake of rice plants is crucial for vegetative growth and crop production. On the other hand, N uptake is influenced by levels of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ in the soil.

Results of correlation analysis between observation parameters indicated a significant relationship between $N\text{-}NO_3^-$ content in soil with $N\text{-}NH_4^+$ content in soil (r = 0.871). This leads to a very significant relationship between effective weight of harvested dry grain and effective weight of milled dry grain (r = 0.993).

Table 6. The effect of urea-humic acid dosages on plant's content and uptake of nitrogen

Treatment	Content at 56 dap			Uptake at 56 dap (g kg^{-1})
	$N\text{-}NH_4^+$ (ppm)	$N\text{-}NO_3^-$ (ppm)	N total (%)	N total
U	37.784 abc	5.974 a	1.179	7.190
UH1	6.265 ab	11.144 ab	1.311	7.220
UH2	58.313 c	10.953 a	1.428	7.490
UH3	7.270 ab	27.721 b	1.186	6.720
UH4	43.127 bc	5.216 a	1.277	8.880
UH5	5.200 a	2.600 a	1.279	8.030

Remarks: * Numbers with the same letter in the same column are not significantly different at 5% level of Duncan's test; ** dap = day after planting

CONCLUSION

Urea-humic acid with 5 levels of dosages performed on paddy soil Vertisols in The Experimental Station of Research Center for Legume and Tuber Crop, Ngale, Ngawi, East Java, Indonesia showed a highly significant effect on soil's N-NH_4^+ at 28 dap and soil's N-NO_3^- at 42 dap. The urea-humic acid treatment on all dosages observed can increase plant growth (plant height, number of tillers, and total dry weight) when compared with urea only. The highest result is obtained in the UH2 treatment (100% urea-humic acid) on the parameter of effective weight of harvested dry grain (5.561 t ha^{-1}) and effective weight of milled dry grain (4.611 t ha^{-1}). A significant correlation is obtained between the content of N-NO_3^- and N-NH_4^+ in the soil, as well as a highly significant correlation between effective weight of harvested dry grain and effective weight of milled dry grain. The efficiency of urea-humic acid fertilizer at 100% recommended dosage (UH2) on the effective weight of harvested dry grain and effective weight of milled dry grain is 22% compared to the recommended urea fertilizer (200 kg ha^{-1}).

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