NANO TECHNOLOGY OF ZEOLITE MINERAL FOR SLOW RELEASE NITROGEN OF UREA FERTILIZER ON VERTISOLS PADDY SOIL

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ABSTRACT

A Series Of experiments aimed to study the effect of zeolite as soil conditioner to the nitrogen (N) uptake, and to the dry rice grain yield in the greenhouse and the field condition have been done. The zeolites in this research was zeolite with trade mark Zeolite Kap Kan (ZKK). The results show that the higher addition of ZKK zeolite, the higher N concentration was observed. The highest N concentration (2.96%) was obtained at dosage of 1 ton ZKK ha\(^{-1}\). The weight of dry rice grain yield in the greenhouse increased with the addition of zeolite. Similar tendency was observed when zeolite was used as soil conditioner in field. 6.52 ton ha\(^{-1}\) of dry rice grain has been reached at the ziolite addition of 2 ton ZKK ha\(^{-1}\).

Keywords: Slow Release, Ammonia, Zeolite, Paddy soils; Vertisols.

INTRODUCTION

Four years succesion, 2005 – 2009, rice production in Indonesia has increased because of fertilizer subsidization, irrigation improvement, and using of high yielding varieties. Since 2007, Indonesia success to reach rice self sufficient for the second time and have positively effect to the increasing farmer income. Rice production year 2007 – 2008 was increased from 57.16 million tons in 2007 become 60.33 million tons in year 2008, its mean that has happened the increased rice production more or less 3.69% or surplus 3.17 million tons dry grain yield. Dry grain yield year 2009 with target 63.5 million tons, till Juny 2009 was 63.8 million tons or reach out for 100.5% from target year 2009. In the coming year, it difficult to increase dry grain yield without contribut ion of technology innovations such as the application of zeolite as soil conditioner.

In other hands, the use of anorganic fertilizer such as urea for long time is not efficient due to the high dosage, i.e. more than 300 kg ha\(^{-1}\), and especially the applied urea fertizer is not mixed well into the soil up to 20 cm in deep, thus the production cost will be very expensive. The farmer usually spread the urea fertizer in upper layer of the soil only, sothat the fertilizer is not mixed well into the soil as deep as 20 cm. Consequently, many NH\(_4\)\(^+\) ion (about 70%) are lost through leaching both horizontally and vertically,as well as the denitrification and the volatilization of ammonia (NH\(_3\)).

Practically, the use of urea fertizer result in relatively low NH\(_4\)\(^+\) efficiency uptake, about 30%. However, the NH\(_4\)\(^+\) uptake efficiency can be increased with the technology innovation using zeolite as soil conditioner. It is because of zeolite has unique cationic exchange, adsorption, hydration-dehydration, and catalytic properties. Technically, the
Zeolite can be applied by following several methods, e.g. (1) the zeolite can be directly applied to the soil and followed by urea fertilizer; (2) the urea fertilizer is mixed with zeolite in a proportional dosage (70% urea : 30% zeolite), then is granulated by granulator and applied to the soil; (3) The zeolite is formulated with urea fertilizer an other nutrients proportionally, i.e. the zeolite is mixed with urea, compost of animal feces or rice straw compost, and other nutrient from anorganic fertilizer (P, S, Zn, and Cu) in the form pellet.

Zeolite have prompted their use in recent years in a wide variety of agricultural processes as soil conditioner, slowly released fertilizer, heavy metal (Cu, Cd, Pb, Zn) trapper, dietary supplements in animal nutrition, carrier of insecticides, herbicides and fungicides, and deodorizers and moisture-control agents for animal manure[1]. Zeolite as soil conditioner is suggested to improve the physical, chemical, and biological characteristics of soil [2,3,4]

The typical zeolite characteristics are three-dimensional crystal structure having abilities to hydrate and dehydrate reversibly and to exchange some of their constituent cations. When urea fertilizer is added together with zeolite into the paddy soils, NH₄⁺ cations will be trapped temporarily in the zeolite pores and then it is slowly released to be taken up by the crop root. Therefore, the zeolite are playing the role for holding NH₄⁺ cations, result in the increasing of the efficiency of NH₄⁺ cations uptaken. It was reported that urea fertilizer in the soil could be suppressed by making slow release fertilizer (SRF) which is made from mix up urea and zeolite with ratio 70% urea : 30% zeolite, sothat the used of urea fertilizer could be saved up to 30% [5]. Comparing to the other soil conditioner (such as lime and gypsum), zeolite was stable and the tendency of its residual effect in the soil relatively higher.

The amount of NH₄⁺ cations from urea fertilizer enter the porous space of zeolite structure in relation to ion-exchange depends on a number of other factors: (i) framework topology (channel configuration and dimensions), (ii) size and shape (polarizability) of the ions, (iii) charge density in the channels and cages, (iv) valency and charge density of the ions, and (v) electrolyte composition and concentration in the external solution[6]. Based on XRD determination, more than 50% of zeolites are dominated by clinoptyllolite and modernite structure which are the higher cation exchangeable capacity (CEC) and the higher ion-exchangeable. Therefore the NH₄⁺ cations from urea fertilizer can enter the porous space of zeolite. The NH₄⁺ cations in the porous zeolite will be slowly released to be taken up by the root crop.

The result of zeolite affectivities test demonstrated that zeolite having trade mark ZKK with 6 ton ha⁻¹ dosage could increase the yield of dry rice grain almost 20%. That is the average yield of dry rice grain without zeolite was 61.22 gram per pot, while the dry rice grain yield with zeolite was 73.30 gram per pot [7]. Similarly, zeolite having trade mark ZKK with 800 kg ha⁻¹ dosages were mixed with compost of animal feces could increase the corn dry grain yield 8.44 ton ha⁻¹ higher than without ZKK with the corn dry grain yield 5.65 ton ha⁻¹[8]. The implementation of zeolite and organic fertilizer is reasonable as effort for improving soil degradation.

The objectives of this research were: (1) to study the effect of zeolite to the nitrogen (N) upatake in the greenhouse condition; (2) to study the efect nanotechnology of zeolite to the dry rice grain yield in the greenhose condition; (3) to study the effect zeolite to the dry rice grain yield in the field condition.

MATERIALS AND METHODS

Experiment-I:
The first experiment have been conducted in the greenhouse using small pot which is filled 2 kg dry soils of the Vertisols soil order from Ngawi (East Java) and have been inundated for three weeks until become muddy. Randomized block design to be used as
experiment design consist of 10 treatments which is replicated three times. Those treatments were: (1). Complete control; (2) NPK-farmer; (3). NPK-soiltesting; (4). 125 kg ZKK ha$^{-1}$+NPK-soil testing; (5) 250 kg ZKK ha$^{-1}$+NPK-soil testing; (6). 500 kg ZKK ha$^{-1}$+NPK-soil testing; (7). 1.000 kg ZKK ha$^{-1}$+NPK-soil testing; (8). 2.000 kg ZKK ha$^{-1}$+NPK-soil testing; (9). 4.000 kg ZKK ha$^{-1}$+NPK-soil testing; (10). 8.000 kg ZKK ha$^{-1}$+NPK-soil testing. The test crop was rice of Ciherang variety 12 days old have been planted three crops per pot, then harvested after 6 weeks after transplanting, then leaf samples were analyzed for measurement the N concentration.

Experiment-II:

The second experiment using the same as soils in the experiment-I, but using bigger pot which is filled 8 kg dry soils and have been inundated for three weeks become muddy. The treatments were constructed into seven levels as follow: 1/8, ¼, ½, ¾, 1, 1 ½ and 2 x ZKK-Nanotechnology, where 1 x ZKK were zeolite nano technology formulation consist of mixing of 2.000 kg ZKK+ 2.500 kg rice straw compost + 350 kg urea ha$^{-1}$ + 50 kg (NH$_4$)$_2$SO$_4$ ha$^{-1}$ + 100 kg KCl ha$^{-1}$ + 350 kg rock phosphate ha$^{-1}$ + 10 kg ZnSO$_4$ ha$^{-1}$ + 10 kg CuSO$_4$ ha$^{-1}$ + 1 kg Borax ha$^{-1}$ + 50 kg FeCl$_3$ ha$^{-1}$. The test crop was rice of Ciherang variety 12 days old have been planted three crops per pot, then harvested after 16 weeks after planting.

Experiment-III:

The third experiment have been conducted in five villages in two subdistrict Padas and Kasreman respectively at Ngawi district (East Java Province). After the first plowing, then land preparation to be plotted sized 5 meter x 10 meter and followed by the second plowing until the topsoil become muddy. Randomized block design to be used as experiment design consist of 9 treatments which is replicat ed three times. Those treatments were: (1). NPK-farmer; (2). NPK-soiltesting; (3). 250 kg ZKK ha$^{-1}$ + NPK-soil testing; (4). 500 kg ZKK ha$^{-1}$ + NPK-soil testing; (5). 1.000 kg ZKK ha$^{-1}$ + NPK-soil testing; (6). 2.000 kg ZKK ha$^{-1}$ + NPK-soil testing; (7). 4.000 kg ZKK ha$^{-1}$ + NPK-soil testing; (8). 8.000 kg ZKK ha$^{-1}$ + NPK-soil testing; (9). Urea mixed with zeolit (70% urea: 30% zeolite) + PK-soil testing. Rice crop variety Ciherang have been planted three crops per hole at a distance 20 cm x 20 cm.

RESULTS AND DISCUSSION

Experiment-I:

The effect of zeolite to the nitrogen concentration and nitrogen uptake to the rice crop for 6 weeks old after transplanting have been represented in Figure 1.
The higher addition ZKK 125 – 1.000 kg ha\(^{-1}\), the higher N concentration was observed, except at 250 and 500 kg ZKK treatment level were 2.62 and 2.69% respectively. The highest N concentration at level 1.000 kg ZKK was 2.96%. The higher level at level 2.000 (No.8), 4.000 (No.9), and 8.000 kg (No.10) ZKK ha\(^{-1}\), the lower N concentration, it caused NH\(_4\)\(^+\) cations entered zeolite porous but will be slowly released. Hypothesis: “The wider ratios between zeolite to urea, the higher NH\(_4\)\(^+\) cations entered the porous space zeolite and NH\(_4\)\(^+\) cations much stronger fixed in the zeolite porous with high negative charge because of high value of the cation exchangeable capacity (CEC), so NH\(_4\)\(^+\) cations much slower release. The nanotechnology in relation to the mixing zeolite and urea material proportionally could increased NH\(_4\)\(^+\) uptake to the crop, but it should be proofed in the future research to study relation between zeolite with high CEC value which is mixed to the soil in the rooting zone and the ability NH\(_4\)\(^+\) cations could be slowly released from the zeolite porous space to the soil, then it could be taken up by the crop root.

It have been proved with fact, that the highest N uptake as many as 623 gram/pot at level 125 kg ZKK ha\(^{-1}\) was pointed out that the amount NH\(_4\)\(^+\) cations entered porous space zeolite correlated to zeolite CEC which is characterized with negative charge in the porous space of zeolite which have a nano size (1–100 nm). The higher quality of zeolite, the better of reversible ion-exchange is. It is when the minimum number of zeolite mineral was 50% and the CEC value of zeolite higher than 100 cmol\((+)\) kg\(^{-1}\).

**Experiment-II:**

The effect level Zeo-Nano (1/8, ¼, ½, ¾, 1, 1 ½, 2 x ZKK) significantly different to the dry rice grain yield 6 weeks after transplanting in the greenhouse condition (Figure 2).

![Figure 2: The effect level Zeo-Nano (1/8, ¼, ½, ¾, 1, 1 ½, 2 x ZKK) significantly different to the dry rice grain yield; Zeo-Nano was formulation of mixing of zeolite with straw of rice compost, urea, ammonium sulphate, rock phosphate, micronutrient Cu, Zn, and B in the form pellet.](image)

The highest weight of dry rice grain yield in this study increased with the addition of zeolit and reached 40 gram/pot at level 2 x Zeo-Nano (No.8). The weight of dry rice grain yield was 40 gram/pot at level 2 x Zeo-Nano significantly different to the all treatments and totally higher than the control one which is only 15 gram/pot. Although in the short-term the utilization high level of 2 x Zeo-Nano was not profit yet, but if the Zeo-Nano added at low level (1/4 x Zeo-Nano) continuously at each planting time of rice, undoubtedly its effect not only the dry rice grain yield could be increased, but also the physical, chemical, and biological soil characteristics could be improved in relation to the sustainable agriculture.
Nano Technology of Zeolite Mineral......

achieved. According to Zeo-Nano formulation which have been made of mixing zeolite, rice straw compost, urea, ammonium sulphate, rock phosphate, KCl, FeCl₃, CuSO₄, ZnSO₄, and Borax, then the C, N, Fe, Cu, Zn, Mg, Al, Si, P, S concentration have been detected with SEM-EDS (scanning electron microscope-energy dispersive spectrometry) (Figure 3).

Zeolite from this formulation was pointed out by concentration of oxygen (45.87%), silicate (13.25%), and aluminum (3.23%). The ratios of Si: Al was 4/1 have proofed that zeolite with trade mark ZKK produced by CV. Mina Tama at Bandar Lampung was the best zeolite. Carbon content (20.98%) was came from rice straw compost, while N (7.77%), S (0.22%), P (0.64%), K (1.78%), Fe (1.27%), Cu (0.86%), Zn (0.43%) were came from anorganic fertilizer. Actually, SEM-EDS not detected particle nano less then 2 nm. For detecting particle nano less then 2 nm should be used transmission electron microscope (TEM).

![Figure 3](image)

**Figure 3:** The C, N, Fe, Cu, Zn, Mg, Al, Si, P, S concentration has been detected with SEM-EDS (scanning electron microscope-energy dispersive spectrometry)

**Experiment-III:**

The highest dry rice grain yield as many as 6.520 ton ha⁻¹ has been reached at the addition 2 ton ZKK ha⁻¹. It is totally higher than the control one which is only 2 ton ha⁻¹ (Figure 4).

![Figure 4](image)

**Figure 4:** The effect level zeolite (ZKK) to the dry rice grain yield
The addition of ZKK more than 2 ton ZKK ha\(^{-1}\), the dry rice grain yield decreased. The higher level ZKK, the higher NH\(_4^+\) cations entered the porous space zeolite and NH\(_4^+\) cations much stronger fixed in the porous space zeolite, and NH\(_4^+\) cations from urea slower release NH\(_4^+\) cations. But the residual NH\(_4^+\) cations could be released for the next rice crop; moreover zeolite in the soil could not break down.

**CONCLUSION**

Based on the above results it can be concluded that:
1. The higher addition ZKK 125 kg ha\(^{-1}\) ~ 1 ton ha\(^{-1}\), the higher N concentration was observed, except at level 250 and 500 kg ZKK ha\(^{-1}\) that were 2.62 and 2.69%, while the highest N concentration at level 1 ton ZKK ha\(^{-1}\) was 2.96%.
2. The highest weight of the dry rice grain yield was 40 gram/pot at level 2 x Zeo-Nano.
3. The highest weight of the dry rice grain yield as many as 6.520 ton ha\(^{-1}\) has been reached at the addition 2 ton ZKK ha\(^{-1}\).

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**REFERENCES**


