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Research Paper

Growth response of corn due to application of simple mixed compound fertilizer derived from urea - azolla (*azolla sp.*) - coal fly ash

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Abstract

Mixing urea with natural materials that can reduce the rate of urea dissolution is known to increase the N availability replenished by inorganic fertilizers which are absorbed by plants for growth and production. This study aimed to examine the effectiveness of the application of pellet N fertilizer prepared by coal fly ash-azolla and urea on the response of corn planted in acidic Ultisol. This pot experiment was performed in the greenhouse and soil analysis was conducted in the Laboratory of Chemistry, Biology, and Soil Fertility, Soil Science Department, Faculty of Agriculture, Sriwijaya University. The research was arranged using a completely randomized design with nine treatments and three replications. The treatments applied were a mixed composition materials (w/w) of 50% coal fly ash + 50% azolla, and 40% coal fly ash + 60% azolla respectively. Each composition (w/w) of 70% coal fly ash-Azolla mixture was then incorporated by 30% urea and compacted as pellets using a manual screw extruder. In addition, to compare the effect of the pellet, another treatment with granular urea fertilizer was applied by immersing and sowing on the soil surface. The results showed that the application of N slow-release using the pellet forms significantly increased N availability, plant N uptake, plant height, and dry weight of corn. The N slow-release as a pellet can reduce the dose of N inorganic fertilizer as urea by 25%. The response of corn at a dose of 0.75 times is not significantly different from the dose of 1 times the recommended dose of N (138 kg N ha^{-1}).

Keywords

Coal Fly Ash, Azolla Biomass, Corn, Ultisol, Urea, Pellet fertilizer

1. INTRODUCTION

The efficiency of N inorganic fertilization is very low and around 40–70% of the N fertilizer applied into the soil is lost to the environment and cannot be absorbed by plants (Trenkel, 2010; Lubkowski, 2014). This condition not only causes economic and resource losses but also has the potential to cause environmental pollution (Ali and Danafar, 2015; Lubkowski, 2016; Dimkpa et al., 2020). One effort to solve the problem is by coating the N inorganic fertilizers using natural materials. The coating of N fertilizers is expected to release the N gradually or slowly to the root zone. The rate of N dissolution and release from the fertilizers is controlled by the rate of diffusion through the coating material. Layers with high porosity and high dissolution rate will cause the fertilizer to become more easily and quickly dissolved into the soil solution. Therefore, the N dissolution rate is highly dependent on the type of coating material used (Trenkel, 2010; Lubkowski, 2014).

The coating materials that can be used are generally divided into two types, namely inorganic minerals and organic polymers. The use of inorganic minerals as coating materials is more expensive compared to organic polymers Dong et al. (2016). The popular inorganic minerals used as a slow-release coating are sulfur, gypsum, lime, cement, zeolite, and fly ash (Qiu and Hlavacek, 2010; Qiu et al., 2011; Hou et al., 2014; Dimkpa et al., 2020). Unfortunately, Qiu and Hlavacek (2010)) showed that the effectiveness of inorganic minerals in the fertilizer coating is lower compared to organic polymers.

Coal fly ash is a material produced from coal combustion that can be used as a fertilizer coating material. Coal fly ash is dominated by ferro-aluminosilicate minerals, fine texture with a size of $0.01 - 100\mu m$ and has pozzolanic properties (such as cement) (Yousuf et al., 2020). Fine coal fly ash contains a lot of Ca^{2+} cations followed by Mg^{2+}, Na^{+} and K^{+} (Kishor et al., 2010; Hamanaka et al., 2022) and plays a role as essential elements for plant growth. In addition, organic matter can be used as a fertilizer coating material and by binding cations such as ammonium from urea through chemical reactions directly or indirectly by microbiological activity (Tan, 2003; Havlin et al., 2005; Teixeira et al., 2016). The use of a mixture of coal fly ash-organic material can increase the efficiency of N, P, and K fertilizers by 45.8%, 33.5%, and 69.6%, respectively and the availability of these nutrients is higher than using chemical fertilizers alone or a combination of chemical fertilizers and organic matter (Kishor et al., 2010). Hermawan et al. (2014) also reported that the use of a mixture of coal fly ash-chicken manure can increase the efficiency of P fertilizer by 42.4%.

Based on the previous studies, the coal fly ash and azolla have good potential to be used as materials for slow-release fertilizers. The mixture of coal fly ash-azolla as a coating is 70% of the mixture of coal fly ash and azolla and 30% urea, and the mixture is prepared as compacted briquettes showing certain physical characteristics such as hardness, bulk density, porosity, and water-holding capacity. The mixture easily dissolves into the soil solution, as indicated by dissolved solids value, electrical conductivity, and pH. In addition, the N content of this mixture is higher than the other compositions and indicates N releasing from urea slowly (Hermawan et al., 2018). Therefore, it is very important to conduct this study to determine the effectiveness of the application of N fertilizer slow release in a pellet fertilizer derived from coal fly ash-azolla-urea on the response of corn in acidic Ultisol.

2. EXPERIMENTAL SECTION

2.1 Preparation of Pellets Slow Release Fertilizer

Azolla biomass was taken from the azolla-cultured pond at the Soil Science Department, Sriwijaya University. Coal fly ash was obtained from a coal-fired thermal power station in Muara Enim District, South Sumatra. The chemical characteristics of the azolla biomass used in this study are as follows: pH 5.75, C-Organic 36.80 g kg^{-1}, Total N 18.9 g kg^{-1}, Total P 1.65 g kg^{-1}, and Total K 18.50 g kg^{-1}. Meanwhile, the characteristics of the used coal fly ash are dominated by silt and clay-sized particles 715.20 g kg^{-1}, pH 8.74, C-Organic 0.10 g kg^{-1}, Total N 0.01 g kg^{-1}, Total P 0.5 g kg^{-1}, and Total K 0.5 g kg^{-1}.

The experiment was conducted in the Laboratory of Chemistry, Biology and Soil Fertility, Soil Science Department, Faculty of Agriculture, Sriwijaya University. A simple mixed compound as pellet fertilizer was made by mixing composition materials (w/w) of 50% coal fly ash + 50% azolla, and 40% coal fly ash + 60% azolla respectively. Each composition (w/w) of 70% azolla-coal fly ash mixture was then incorporated by 30% urea. Before mixing, the urea and azolla biomass were mashed and filtered using a sieve with a 2.0 mm size. Coal fly ash was also pulverized and filtered using a sieve with a 0.05 mm size. After that, both materials were mixed homogeneously using deionized water until forming a paste containing 40% moisture content. The mixture was put into a screw extruder. The resultant N pellets were dried using an oven at 500 C for 24 hours with 10-15% moisture content. The N pellet fertilizer was prepared from raw material (azola + coal fly ash) + urea with a composition of (50:50)70+30 (SR-A) and (60:40)70+30 (SR-B), having a pH value of H2O (1: 1) 7.30 and 7.15, total N of 106.70 and 106.20 g N kg^{-1}, and C-Organic of 143.50 and 150.80 g C kg^{-1} respectively.

2.2 Experimental Design

This pot experiment was conducted in the Greenhouse of the Soil Science Department, Faculty of Agriculture, Sriwijaya University. Ultisol used in this study was taken from the Arboretum of the Soil Science Department, Faculty of Agriculture, Sriwijaya University. The soil was classified as acidic with a pH of 4.41. The content of C-organic was 3.28 g kg^{-1} and N-total was 0.34 g kg^{-1}, both of which were very low. The available P was also low, with a value of 5.58 mg kg^{-1}. Cation Exchange Capacity (CEC) was low, with a value of 10.8 cmol(+) kg^{-1}. Base cations such as K, Na, Ca, and Mg ranged from low to very low. Moreover, the soil texture was categorized as sandy loam, with a clay content of 376.6 g kg^{-1}.

The research was arranged using a Completely Randomized Design with three replications. The treatments applied were N pellet fertilizers made from raw materials consisting of azolla, coal fly ash, and urea with compositions of $(50:50)70+30$ (SR-A) and $(60:40)70+30$ (SR-B). Each composition (w/w) of 70% coal fly ash-Azolla mixture was then incorporated with 30% urea to form an N pellet fertilizer. These N pellet fertilizers (SR-A and SR-B) were applied at doses of 1 times the recommended dose (SR-A1 and SR-B1), 0.75 times the recommended dose (SR-A2 and SR-B2), and 0.5 times the recommended dose (SR-A3 and SR-B3). To compare the effectiveness of the N pellet fertilizer, granular urea was applied alone at a dose of once the recommended dose, either by immersing (UB-1) or sowing on the soil surface (UB-2). The recommended 1-time dose is 138 kg N ha^{-1}. The N pellet fertilizer was applied by immersion to a depth of 10 cm from the soil surface at the time of planting. Granular urea was broadcasted in two ways: immersed at a depth of 10 cm from the surface at the time of planting and given gradually at planting 14 DAP (Days After Planting) and 28 DAP. Basic fertilizers such as KCl (60% K_2O) and SP36 (36% P_2O_5) were each applied at a dose of 100 kg ha^{-1} as base fertilizers before planting. Hybrid corn seeds were planted, three seeds per pot, and were thinned to one plant per pot after 10 days. Maintenance included daily watering, weed control, and pest and disease control using pesticides as needed.

2.3 Data Collection and Analysis

The plant variables measured during the study included plant height (cm), dry weight of plant stover (g plant^{-1}), and plant N uptake (mg plant^{-1}) during the anthesis phase. In addition to these, soil parameters were analyzed, including pH in a H_2O 1:1 solution and N-total (g kg^{-1}).

Statistical analysis was performed on the collected data.

An Analysis of Variance (ANOVA) was conducted to assess the influence of the treatments on the observed variables. This was followed by a Least Significance Difference (LSD) test to discern differences between individual treatments.

3. RESULTS AND DISCUSSION

3.1 Changes in Some Soil Chemistry

3.1.1 Soil pH

Analysis of variance (ANOVA) conducted on soil pH values revealed that the treatments had no statistically significant impact on soil pH during the anthesis phase of corn growth. However, certain trends were observed. Soil pH in both the control group and those treated with granulated urea (UB) exhibited a tendency to be lower compared to the soils treated with N pellet fertilizer, as can be seen in Table 1 and Figure 1.

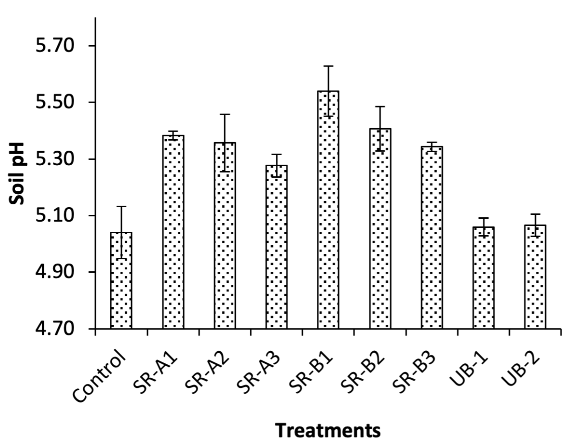

Figure 1. Soil pH at the anthesis phase of corn in each treatment

Moreover, N pellet fertilizers applied at the recommended dose level, specifically N pellet fertilizer A (SR-A1) and N pellet fertilizer B (SR-B1), tended to yield a higher soil pH relative to the pellets applied at lower dosage levels (Table 1).

3.1.2 Total N Soil

Results of analysis of variance (ANOVA) showed that the treatment had a significant effect on total N soil at anthesis phase. Figure 2 shows that the total N soil due to N fertilization, both in the form of N pellets (SR) and granular urea (UB), tended to be higher than control. In addition, the total N soil in the pellet fertilizer (SR) tended to be higher than the urea fertilizer (UB).

Furthermore, the results of least significant difference test (LSD) (Table 1) showed that the N-total soil in the treatment of N pellet fertilizer A (SR-A) at a dose of 1 times the recommended dose of N (SR-A1) was not significantly different when compared to N pellet fertilizer B (SR-B) at

Table 1. Effect of the treatment on the soil pH and total N content at the anthesis phase of corn plants

Treatment	Variable	
	soil pH H_2O (1:1)	N-total (g kg^{-1})
Control	5.04	0.54 a
SR-A1	5.38	0.92 d
SR-A2	5.36	0.97 d
SR-A3	5.28	0.64 ab
SR-B1	5.54	0.86 cd
SR-B2	5.41	0.84 bcd
SR-B3	5.34	0.73 bc
UB-1	5.06	0.71 b
UB-2	5.07	0.71 b
$LSD_{0,05}$	ns	0.14

Remarks: numbers followed by the same small letter in column are not significantly different (P < 0.05); ns: not significant

a dose of 1 times the recommended N dose (SR-B1), with N pellet fertilizer treatment at a dose of 0.75 times the recommended N dose (SR-A2 and SR-B2), and significantly higher than control, N pellet fertilizer at a dose of 0.5 times the recommended N dose (SR-A3 and SR-B3), and with granulated urea at the dose of 1 times the recommended N dose is applied at the same time at planting (UB-1) or at stages UB-2. This condition indicates that the use of N fertilizer in the form of pellets coming from a mixture of azolla and coal fly ash can increase the total N soil.

3.2 Corn Response

3.2.1 Plant Height

The results of analysis of variance on plant height at the anthesis phase showed that the treatment had a significant effect on plant height. Figure 3 also shows a tendency that the plant height in the N pellet fertilizer was higher than control and granular urea (UB).The height of corn treated by N pellet fertilizer at a dose of 1 times the recommended dose of N (SR-A1) did not show a significant difference compared to the treatment with other N pellet fertilizer doses, but was significantly higher than the control and granular urea (UB) (Table 2). These results indicated that the response of corn treated by N fertilizer in the form of pellets prepared by urea combined with azolla and coal fly ash tended to be better than granular urea.

3.2.2 Dry Weight

Plant dry weight showed that the response of corn on N fertilization and describes the amount of nutrients absorbed by crop that can be converted into plant tissue. Data from analysis of variance showed that the N fertilization had a significant effect on the dry weight of shoots and not

Table 2. Effect of the treatment on the plant height, dry weight of shoot and N uptake of corn at the anthesis phase

Treatments	Variable			
	Plant Height (cm)	Plant Weight (g pot^{-1})	Plant Root Weight (g pot^{-1})	N Uptake (g plant^{-1})
Control	122.00 a	12.38 a	2.21	0.29 a
SR-A1	156.00 c	25.80 bc	4.35	0.70 c
SR-A2	149.83 c	26.92 bc	4.83	0.61 bc
SR-A3	148.00 bc	23.54 bcd	3.86	0.58 bc
SR-B1	134.17 abc	28.47 d	3.63	0.69 c
SR-B2	149.67 c	20.94 abcd	4.15	0.60 bc
SR-B3	144.33 abc	22.20 abcd	3.80	0.56 bc
UB-1	124.33 ab	17.08 abc	2.47	0.49 abc
UB-2	121.83 a	15.10 ab	2.54	0.43 ab
$LSD_{0,05}$	23.80	10.28	ns	0.24

Remarks: numbers followed by the same small letter in column are not significantly different (P < 0.05); ns: not significant

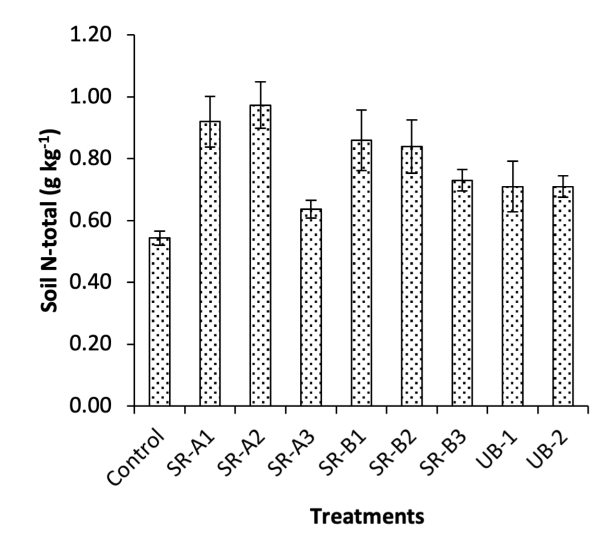

Figure 2. Total N content in soil at the anthesis phase of corn in each treatment

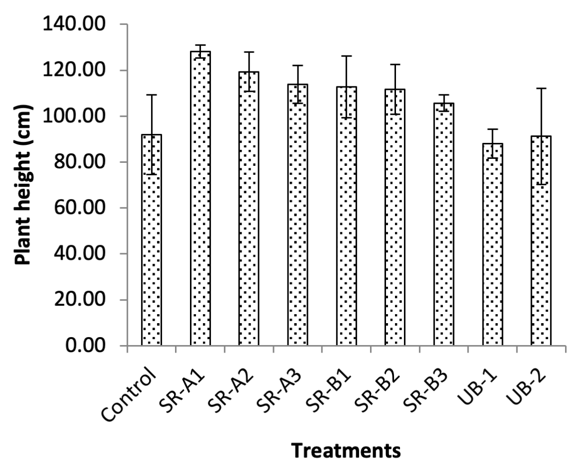

Figure 3. Plant height at the anthesis phase of corn in each treatment

significantly influence on the dry weight of roots. Figure 4 and Figure 5 show that the N fertilization tended to have a higher plant dry weight than control. In addition, N pellet fertilizer (SR) tended to give higher plant dry weight than granulated urea (UB).

The results of least significant difference test (LSD test) (Table 2) showed that dry weight of shoot in the treatment of N pellet B at at a dose of 1 times the recommended dose of N (SR-B1) was not significantly different when compared to the N pellet fertilizer at a dose of 1 times the recommended dose (SR-A1) and with N pellet fertilizer at a lower dose, and significantly higher than the control, and with granulated urea at 1 times the recommended dose, either given at the same time of planting (UB-1) or broadcasted gradually (UB-2). This condition indicates that the use of N pellets prepared by a mixture of coal fly ash and azolla can increase the dry weight of shoot, even at lower N doses.

Although it did not show a significant difference, the average of dry weight of shoot at the anthesis phase (Table 2) in the treatment of N pellet fertilizer with a composition of 30% urea and 70% mixture of azolla and coal fly ash at a composition of 50: 50 (SR-A) tended to be heavier than the composition of 30% urea and 70% mixture of azolla and coal fly ash at composition 60: 40 (SR-B). The opposite condition occurred in the dry weight of roots (Table 2). This could be due to the addition of more azolla in SR-B resulting in plant root was better. The dry weight of the plant was not significantly different between all doses of N in the

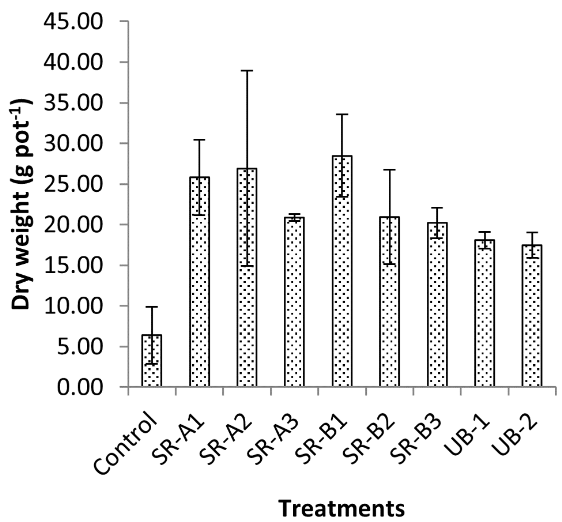

Figure 4. Dry weight of shoot in anthesis phase of corn in each treatment

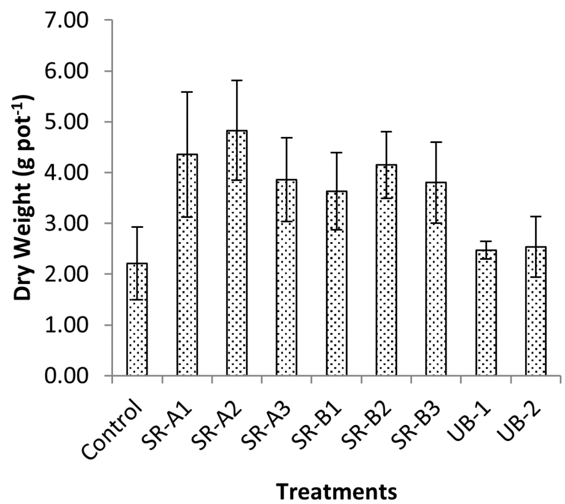

Figure 5. Dry weight of corn roots in anthesis phase in each treatment

pellet fertilizer treatment, presumably because the mixture of coal fly ash and azolla with urea could provide more N during the plant growth. This condition is also indicated by dry weight of the plant which tended to be lower in the treatment of ordinary urea (UB) (Table 2). These results indicate that nutrient N pellet can be available and absorbed by plants slowly during the period of plant growth.

3.2.3 N Uptake

The results of analysis of variance of N uptake at anthesis phase at each dose of N pellets derived from a mixture of azolla - coal fly ash - urea showed that the treatment had a significant effect on the N uptake. Plant N uptake due to pellet fertilizer treatment (SR-A and SR-B) was significantly higher than control. Meanwhile, increasing the dose of N pellet fertilizer did not show a significant difference in plant N uptake (Table 2).

Furthermore, Figure 6 shows that the N uptake coming from pellet fertilizer tended to increase with increasing the dose N fertilizer, both of a pellet fertilizer A and B tended to be higher than urea (UB). This indicates that N from pellet fertilizer tended to be absorbed by plants slowly better than N from ordinary urea. The increase in N uptake was thought to be related to an increase in soil N (Table 1). Higher N uptake also indicates higher N utilization efficiency and correspond to dry weight of the plant (Table 2).

4. Discussion

The variation of soil pH is thought to be caused by the addition of some natural materials that can increase soil pH from N pellet fertilizer, namely coming from the coal fly ash and organic matter of azolla. Decomposition of azolla assumed to produce negative electrons which will be neutralizing the positive charge on the colloid system and causing an increase in negative charge on colloid surface (deprotonation), this is causing soil pH tends to be higher (Stevenson, 1994; Sposito, 2008). Meanwhile, coal fly ash is generally resulting in alkaline condition and rich in bases such as Ca and Mg. Thus the addition of coal fly ash will increase the pH. Several research results also revealed that the application of coal fly ash and its combination with organic matter can increase the pH of acidic soils (Kishor et al., 2010; Hamanaka et al., 2022). The increase in soil pH, can be caused by the organic acids from the decomposition of organic matter. Ionization of functional groups can produce a number of negative charges on the colloid surface, resulting in an increase of pH (Stevenson, 1994; Sposito, 2008). In addition, Ca and Mg replenished by coal fly ash will decrease the acidity (Pandey and Singh, 2010; Mupambwa et al., 2015).

The organic material from azolla has a fairly high nitrogen. The inorganic N content of the soil released by organic matter will be greater than that of the soil without organic matter. This indicates an increase in biochemical activity of soil through the mineralization of N from organic matter (Yu et al., 2013). The additional of natural material like azolla and coal fly ash as in pellet form suspected that it will reduce the loss of soil N. The higher total N content of the soil indicated that the pellet treatment could reduce the amount of N lost due to leaching and volatilization. Fitriani et al. (2020) revealed that the addition of organic matter would be able to increase plant N uptake and N fertilization efficiency. Mixture of urea with azolla and coal fly ash forming N pellets seems to have been able to reduce the

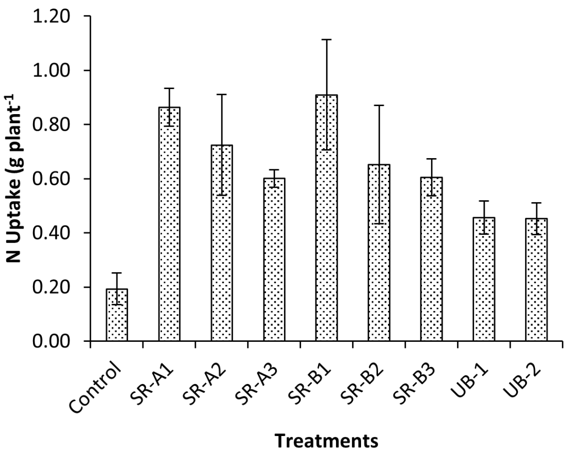

Figure 6. N uptake of corn in the anthesis phase of corn in each treatment

N dissolution rate of fertilizer. Lubkowski (2014) suggests that the N dissolution rate is highly dependent on the type of coating material used. The increase of N supply in plant nutrient uptake is largely determined by root contact with nutrients in soil solution, soil concentration of nutrients and ability to absorb it from the soil (Havlin et al., 2005).

5. CONCLUSIONS

The application of N pellet fertilizer made from a mixture of coal fly ash, azolla and urea can significantly increase soil pH, N availability, N uptake, plant height and dry weight of corn. The simple mixed compound fertilizer as a pellet can reduce the dose of N inorganic fertilizer by 25%. The growth response of corn at a dose of 0.75 times is not significantly different from the dose of 1 times the recommended dose of N as urea. Growth of corn may be increased by Ca and Mg in coal fly ash, or indirect effect by increment of pH.

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