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Full Length Research Paper

Analyzing the Effects of Zeolite-Based Nitrogen Nano-fertilizers on Inceptisol and Alfisol Maize Growth, Yield, and Quality

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By delivering nutrients in a controlled manner that corresponds with crop need, nano-fertilizer technology can increase nutrient use efficiency without having any negative side effects. The current work makes the hypothesis that because nano-zeolite has a large surface area, it can control nitrogen release when coated or mixed with traditional nitrogenous fertilizers. This is a great slow-release fertilizer that helps release nitrogen steadily in proportion to crop development without causing any negative environmental effects. Using maize as a model system, the recently created intercalated N nano-fertilizer formulations were examined. In order to learn more about how nano-fertilizer might boost crop output with improved N use efficiency, the fate of nitrogen in the soil system was investigated. In two greenhouse trials with two different soil textures (Alfisols-Irugur soil series-sandy loam and Inceptisol-Periyanayakkan palayam soil series-clay loam), the response of maize plants to the manufactured fertilizers was evaluated. Nanozeourea consistently had greater grain N contents on alfisols (Control 0.48; Treated 0.76%) and inceptisols (Control: 0.26%; Treated: 0.32%). Compared to inceptisol, the response was stronger in alfisol. Compared to ordinary urea, nanozeourea treatment consistently resulted in greater growth, yield, quality, and nutrient uptake.

Key words: Alfisols; Inceptisols; Nano-fertilizer; Nitrogen; Maize yield; Slow release; Zeolite.

INTRODUCTION

In a system of agricultural production, fertilizers are essential. Fertilizer application in the nation began in the 1960s, coinciding with the green revolution and the introduction of fertilizer-responsive cultivars in Indian agriculture. Although fertilizer application significantly boosted grain development, poor fertilizer response ratios, uneven fertilization, insufficient organic matter, and heightened levels of multi-micronutrient deficits nationwide caused the yields of various crops to stall. Unbalanced fertilization is one of the most important elements to be taken into account for N management among the challenges that soil scientists encounter. In addition to the low price of urea owing to decontrol (subsidized rate), farmers began utilizing nitrogenous fertilizers, especially urea, extensively because N fertilization shows universal response in crops. As a result, the current NPK ratio is 8.2:3.2:1, when the ideal ratio is 4:2:1. This is a very serious problem that is generating eutrophication in aquatic systems and nitrate pollution in ground water. In order to control the nitrification processes and maintain N availability throughout the crop period, slow release fertilizers must be developed. At 100 nm, nanotechnology manipulates materials at the atom, molecule, and macromolecular scales; these scales have very different properties than large-scale ones [1,2]. It changes the mechanical, thermal, and catalytic properties of materials by increasing the surface area to volume ratio. Effective slow-release fertilizers could be created using nanotechnology [3]. As everyone knows, clays play a major role in determining the fertility of soil because of their large surface area and adsorptive sites, which help retain and release nutrients.

If the same clay is reduced by ball milling to a nanometer in size, the surface area increases by many times, to 750 m^2 g^{-1} [5]. One gram of montmorillonite can be dispersed to a dimension of 30-40 m^2 [4]. The "top-down approach," in which the particles are ground to a desired size of 1-100 nm, has been the focus of extensive research. Surfactants have been utilized to stabilize the particles. An additional benefit of the surfactant was that it altered the particle's surface charge, enabling the nanoparticles to retain anionic nutrients (such NO^-). This method has been frequently used to create nitrogen-carrying nanofertilizers [6–10]. Under greenhouse conditions, these nano-fertilizer formulations may improve nutrient utilization efficiency [11]. In order to increase the efficiency of nutrient use while preventing the fixation or loss of nutrients to the environment [13] and providing a variety of nutrients in appropriate proportions [14], nano-fertilizers and nano composites can be used to regulate the release of nutrients [12] from fertilizer granules. In agriculture, zeolite and nanoporous zeolite are applied as a slow-release fertilizer [15,16]. As a slow-release nano-fertilizer, zeolite enhanced availability for 60 days by including urea, potassium sulfate, and calcium hydroxyapatite [17]. Using crystalline and non-crystalline components of soil clays, a synthesised clay polymer nutrient nanocomposite enhanced biomass yield [18]. A slow-release fertilizer for maize that controlled N availability for 45–49 days was created using nanoclays and zeolite [5]. Thus, experiments on Inceptisols and Alfisols were conducted to see how maize plants responded to zeolite-based nano N fertilizer formulations.

2. MATERIALS AND METHODS

Clintoptilolite, a fine-size natural zeolite, was purchased from GM Chemicals in Allahabad. Urea was intercalated and impregnated utilizing both adsorbents to create a unique nano-nitrogen fertilizer based on the loading efficiency of zeolite forms (micro, nano) [3]. In 2012 and 2013, Tamil Nadu Agricultural University conducted experiments in two types of soils (light and heavy textured, i.e., Alfisols - Irugur soil series - sandy loam and Inceptisol - Periyanayakkan palayam soil series - clay loam) to examine how maize (NK-6240) responded to various fertilizer formulations. The physical and chemical characteristics of the first soil samples were examined (Table 1).

In both soil conditions, the five treatments listed below were used. For all five treatments, the suggested N dosage for hybrid maize (250 kg N ha^{-1}) was adhered to. P and K were applied as murate of potash and single super phosphate, respectively, at the prescribed dosages of 75 and 75 kg P_2O_5 and K_2O.

T1 Urea alone

T2 Zeolite + Urea (1:1 ratio – Physical mixing at equal proportion on w/w basis)

T3 Nano Zeolite + Urea (1:1 ratio - Physical mixing at equal proportion on w/w basis)

T4 Zeourea (1:1) – Intercalated

T5 Nanozeourea (1:1) – Intercalated

At 30, 60, 90, and harvest stages, plant height was measured. At 60 DAS [19], before the tassel emerged, the total chlorophyll content in the leaves was measured using a SPAD meter (Minolta SPAD52 meter). By measuring the distance between the base of the stem and the tip of the longest root, the length of the root was calculated and given in centimeters. At the post-harvest stage, the production of dry matter was estimated. The nutrient content concentrations were multiplied by the dry matter to determine the absorption of N. g per pot is the unit of measurement.

2.1 Plant Nutrient Analysis

Distilled water was used to make 50 mL of one gram of digested samples, which were then preserved for additional nutrient analysis. The usual technique was used to determine the nitrogen content of the plant samples. To distill the ammonia, roughly 10 mL of the di acid digest was obtained and put in a micro kjeldahl. The evolved ammonia was collected using 2% boric acid and two to three drops of double indicator. The ammonia was then titrated against 0.02 N sulfuric acid. Blanks were kept the same without any samples added. N (%) content × (6.25) conversion factor was used to estimate crude protein.

2.2 Yield Components

The number of days it took for the silking and tassel to appear was noted. The average length of the cob, measured from bottom to top, was converted to centimeters. The cob's mean girth at maximum girth was measured and reported in centimeters. From the cob collected from the sample plants, the average number of grain rows cob^{-1} was calculated and reported. A mean of the number of grains in each row of the sample plant's cobs was calculated and represented as number of grains row^{-1}. Following drying, the weight of each individual cob was noted, and the mean weight was calculated and represented in g cob^{-1}.The information gathered from several studies was analyzed using DMRT and variance by variance (P =.05) with mean separation by least significant difference (LSD) [20].

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Particularly during the crop's active development stage (60 and

90 DAS), maize plants treated with a new fertilizer formulation made by physically combining urea with zeolite or nano-zeolite or fusing by intercalation methods greatly increased in height. Even though these novel fertilizer formulations boosted growth, early stage and harvest did not show any discernible level of significance. When plants were fertilized with nanozeourea, the treatment difference was clearly visible. While ordinary urea fertilization generated 131.8 cm at 90 DAS, the best treatment recorded a plant height of 144.8 cm. Plant heights in the other treatments were similar. Alfisol showed a similar pattern of findings, however all treatments had values that were 15-20% higher (Table 2).

As a measure of growth, plant height varied depending on the fertilizer source used. The plant grew taller throughout the vegetative development period regardless of the kind of soil or fertilizer used. This growth pattern and outcomes are consistent with the findings of [21] that adding zeolite combined with chemical fertilizer greatly increased sugarcane growth and yield, and [22] that applying zeolite at 20 g and 40 g took the bare minimum of days for the emergence of unifoliate first, second, and sixth trifoliate leaves and plant height of soybean on soil that is allophanic. Corn growth was enhanced when zeolite and wolverine sand were combined [23]. Consuming 2 g of zeolite in 1 kg of soil showed significant impacts on the diameter and leaf area of maize, and it may have an impact on yield when compared to the control treatment [24]. Grain yield and maize plant height were positively impacted by natural zeolite [25].

3.2 SPAD Value

Urea mixed with zeolite or nano-zeolite was compared to the SPAD readings of urea-fertilized maize plants. The SPAD Meter readings for each plant were comparable and not statistically significant (Table 3).

The amount of synthetic nitrogenous fertilizer applied and the light intensity of the maize microclimate during the growth period affected the SPAD meter reading on the amount of chlorophyll at a tassel growth stage. The Minolta SPAD 52 meter non-destructive approach was used to measure the amount of chlorophyll. Similar results showed that the amount of total N in tropical maize was strongly correlated with dry matter yields [26]. Similar results from non-destructive chlorophyll meters have been used to forecast maize's need for N fertilizer [27].

3.3 Root Length (cm)

There was no statistically significant difference in root length in inceptisols between maize plants treated with urea or novel fertilizer formulations (Table 3). On the other hand, plants that were fertilized with nano-urea had the longest roots, with a value that was 9.1% greater than the control. In contrast, alfisol plants fed with nanozeourea had root lengths that were 23.8% longer than those of plants fertilized with urea. The increase in root length could be the result of nanozeolite and the physical interaction of nanozeourea with the root surface. Similar results were reported [28], demonstrating the impact of varying clinoptilolite particle sizes on root development. The treatment with micronized clinoptilolite at the lowest dose of 0.1% resulted in the greatest increase in the weight/length ratio of maize primary roots, whereas the treatment with granular clinoptilolite resulted in a decrease.

3.4 Total Dry Matter (g)

There were no notable differences in the dry matter production of maize plants between the treatments, particularly during the harvest stage in both inceptisol and alfisol (Table 3). The improved N availability brought on by less ammonia loss may be the reason for the maximum dry matter yield seen in soil treated with nanozeourea. Similar results were noted by [29], who discovered that the addition of nanomaterials increased the activity of water and that the plants absorbed more N, P, and K as a result of the water absorption, which in turn boosted the synthesis of dry matter. Similar results [30] showed that the pots treated with gelatin + Cu coated urea and micronutrient coated urea produced the highest dry matter yield (29.25 g pot-1) followed by palm stearin + Cu coated urea (25.5 g pot-1), Agar + Cu coated urea (26 g pot-1), and Cu coated urea (20.75 g pot-1). At the same N application level, the uncoated urea yielded the least amount of dry matter (19 g pot-1). The findings showed that zeolite enhanced with N, P, and K provided a sufficient slow-release source of nutrients for plants. Following consecutive crops of lettuce, tomato, rice, and andropogon grass, the addition of chemical fertilizer (KNO3, K2HPO4, and H3PO4) to zeolite enhanced the production of dry matter and the storage of nutrients [31].

3.5 Days Taken for Tasseling and Silking

In an inceptisol, there was no discernible difference in the number of days required for tasseling or silking. Between 68 and 72 days were needed to reach tassel, while between 78 and 85 days were needed for silking. One of the most notable reactions occurred in plants fed with nanozeo-urea, which took 85 days to silk, two days longer than plants fertilized with urea. There was little variation in the number of days required to achieve tasseling in alfisol. However, there was a notable distinction between black and red soils. Compared to inceptisol, maize plants cultivated in alfisol tasseled 10–14 days earlier. Silking also followed this trend. It took 66 days for plants fertilized with conventional urea, 60.1 days for nanozeourea, and 60.9 days for plants treated with zeolite blended urea (Table 3).

3.6 Nitrogen Content (%)

Fertilization with several types of zeolite-based N fertilizers had a substantial impact on the nitrogen contents of roots, shoots, and grains in inceptisol. The roots of maize plants fertilized with nanozeourea had the highest N content (0.32%), whereas the roots of plants treated with urea had the lowest (0.26%). However, the highest N content (0.78%) was found in plants fertilized with zeourea, which differs significantly from the other treatments. Grain harvested from maize plants fed with nanozeourea had the highest N content. N concentrations in maize plants varied considerably for different fertilizer formulas, even under alfisol. Zeourea or nanozeourea roots absorbed the most nitrogen, although they differed greatly from urea-fertilized or physically mixed urea and zeolite. Compared to other treatments, nanozeourea had noticeably greater nitrogen concentrations in the stover and grains. The N content of grains was 28% greater in maize plants fertilized with nanozeourea (0.76%) than in plants fertilized with urea (0.48%) (Table 4).

The total nitrogen content of the treatments on the sections of maize plants increased significantly as a result of the application of nanozeourea fertilizer. Regardless of the soil, the total nitrogen level was found to be higher in both pot situations. Under all treatments, the total nitrogen concentration of both soils was low for the roots and leaves, but the grain and stover of nanozeourea showed better N uptake. The higher uptake of nitrogen may be due to the delayed release pattern. Low-land rice showed similar outcomes [7]. Sugarcane [21] and the total N uptake in maize[30] plants was obtained highest to lowest as micronutrient coated urea >gelatin + Cu coated urea > Palm stearin + Cu coated urea > Cu coated urea >Agar + Cu coated urea > uncoated urea, which which were 762, 676, 523, 491, 324 mg pot-1, respectively. By increasing nutrient absorption and retaining nutrients in the root zone, zeolites combined with chemical fertilizers improved the long-term quality of the soil [32] and [33] by applying nano-chelate levels. spinach leaves with higher iron and potassium accumulation and lower salt, nitrate, and nitro buildup.

3.7 Yield Parameters

Different N formulations in Inceptisol had a considerable impact on grain yield, but they had no discernible effect on 100 grain weight. Fertilized maize plants with zeourea and nanozeourea showed noticeably greater grain yields per plant. Higher grain yield was recorded in the nanozeourea treatment, which is equivalent to zeourea, even though the test weight was not significant. The zeolite + urea and nano-zeolite + urea treatments had the lowest grain yields. The treatment that received the appropriate amount of nanozeourea in alfisol recorded the maximum grain production, 254 g per plant, which was 38% more than that of traditional urea fertilization. The grain production had increased by 31.5% even with zeo-urea fertilization. Higher values for 100 grain weight were also recorded by the same set of treatments (Table 5).

3.8 Quality Parameters - Crude Protein

Regardless of whether the soil was heavy or light textured, plants treated with nanozeo urea had the greatest crude protein content of maize grains. In black and red soils, the best treatment's crude protein content was 4.9% and 4.7%, respectively (Table 5).

Compared to urea fertilized treatments, the crude proteins found in plants treated with nanozeo urea in red and black soils were 36.1% and 26.1%, respectively. The treatment that received zeolite mixed with urea had the lowest levels of crude proteins. Significant variations were found in the yield components of maize (days required for tasseling and silking, grain and stover yield, and hundred grain weight). It might result from the use of nanozeourea, which releases nitrogen gradually and under control, and from the availability of nitrogen during the crop's growth cycle. Apple growth and yield per tree and per unit area were enhanced by the combined use of zeolite and chemical fertilizer.

This supports the results of [21], which showed that using zeolite and chemical fertilizer increased sugarcane output and sweetness (Brix). The slow/controlled release fertilizer was coated and cemented using kaoline nano-subnano composites [34]. Cucumber and tomato growth, yield, and quality were all enhanced by the nutrient-loaded zeolite (zeopro) [35]. The growth characteristics, output of essential oils, and chemical makeup of Achillea plants were all improved by the compost and zeolite mixture [36]. Eggplant yield and yield components were enhanced by nitrogen fertilizer control and foliar spraying with nano-iron chelate [37].

4. CONCLUSION

Two different soil textures—Inceptisol, a clay loam from the Periyanayakkan palayam soil series, and Alfisols, a sandy loam from the Irugur soil series—were used to assess how the maize plants responded to the artificial fertilizers. Nanozeourea consistently had greater grain N contents on alfisols (Control 0.48; Treated 0.76%) and inceptisols (Control: 0.26%; Treated 0.32%). Compared to inceptisol, the response was stronger in alfisol. Compared to ordinary urea, nanozeourea treatment consistently resulted in greater growth, yield, quality, and nutrient uptake.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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