Increasing Growth and Yield of Shallot Using Nano Zeolite and Nano Crab Shell Encapsulated NK Fertilizer in Entisols and Inceptisols

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ABSTRACT

Nanotechnology can be used to produce slow-release fertilizers. Zeolite and crab shells are materials that can be used as fertilizer encapsulation. This study aimed to compare the effects of nano zeolite and crab shells for encapsulation of nitrogen- potassium fertilizers tested on Entisols and Inceptisols soil on the growth and yield of shallots. The research method used a completely randomized design with three factors. The factors were soil type (Entisol and Inceptisol), coating materials (nano-zeolite and nano-crab shell), and NK fertilizer doses (125:50, 250:100, 375:150, and 500:200). The variables observed include initial soil physical and chemical properties, nanoparticle characterization, growth and yield, and agronomic efficiency. Nanoparticles were characterized using SEM and analyzed using ImageJ. The data collected were tested by ANOVA and Tukey. The ball milling method succeeded in producing 91.41% zeolite and 97.50% nano-sized crab shells. Plant height showed that using crab shells as fertilizer encapsulation with a dose of 125:50 gave better results. The yield of crab shells as encapsulation with a dose of 250:100 in inceptisols was better than that in entisols, but the highest agronomic efficiency (EA) was obtained in zeolite treatment as fertilizer encapsulation with a dose of 125:50.

Keywords: Entisol, Inceptisol, Nano crab shell, Nano zeolite, Slow-release.

ABSTRAK

Nanoteknologi dapat digunakan untuk membuat pupuk slow release. Zeolit dan cangkang kepiting merupakan bahan yang dapat dijadikan enkapsulasi. Penelitian ini bertujuan membandingkan pengaruh nano zeolite dan cangkang kepiting sebagai enkapsulasi pupuk nitrogen dan kalium yang diujikan pada tanah Entisols dan Inceptisols terhadap pertumbuhan dan hasil bawang merah. Metode Penelitian menggunakan Rancangan Acak Lengkap 3 Faktor. Faktor 1: Jenis tanah (Entisol dan Inceptisol), faktor 2: Bahan pelapis (nano-zeolit dan nano-cangkang kepiting), faktor 3: dosis NK dengan rasio 125:50, 250:100, 375:150, 500:200. Parameter yang diamati adalah sifat fisika-kimia tanah awal, karakterisasi partikel nano, pertumbuhan dan hasil tanaman serta efisiensi agronomi. Parikel nano dikarakterisasi menggunakan SEM dan dilanjutkan dengan analisis menggunakan ImageJ. Data diuji dengan ANOVA dan dilanjutkan Tukey. Metode ballmilling berhasil menjadikan 91.41% zeolit dan 97.50% cangkang kepiting berukuran nano. Tinggi tanaman menunjukkan bahwa penggunaan cangkang kepiting sebagai enkapsulasi pupuk dengan dosis 125:50 memberikan hasil yang lebih baik dibandingkan perlakuan lain. Hasil tanaman pada inceptisol menggunakan cangkang kepiting sebagai enkapsulasi dengan dosis 250:100 lebih baik dari entisol, namun nilai efisiensi agronomi (EA) paling tinggi diperoleh pada zeolit sebagai enkapsulasi pupuk dengan dosis 125:50.

Kata kunci: *Entisol, Inseptisol, Nano-cangkang kepiting, Nano-zeolit, Pupuk lepas lambat*

INTRODUCTION

Entisols and Inceptisols have the potential to be used as agricultural land. Entisol has an area of 3.80 million ha, and Inceptisol has an area of about 40.88 million ha in Indonesia. Entisols are soils that have little or no clear horizon development. Sandy land is one of the soils classified as Entisol. According to Tuhuteru et al., (2019), Entisol is one of the soils with low productivity due to low water-holding and storage capacity, high infiltration and evaporation, low fertility and organic matter, and low water use efficiency. Entisol also has a low cation exchange capacity and very low nutrient content, especially nitrogen. Inceptisols are soils modified from their parent material through a soil formation process that can be distinguished from entisols. However, they are not sufficient to

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form horizons needed to form other soil types. The total N content of inceptisol is low (0.15-0.42%), the cation exchange capacity is relatively moderate (14.1-17.3 cmol (+)/kg), the base saturation is relatively low (24-29%), and it has a relatively acidic pH (Safitri et al., 2018).

Shallot is one of the commodities with a fairly high economic value and an increasing consumption level (Burhan & Proyogo, 2019). The level of consumption of shallots during 2002-2021 is relatively fluctuating but tends to increase. Shallot consumption in 2017 and 2018 was 2,570 and 2,764 kg/capita/year, respectively. Meanwhile, shallot consumption in 2019 increased to 2,796 kg/capita/year. In 2020 and 2021, the level of shallot consumption was also predicted to increase by 1.18% and 1.28%, respectively. Shallots can grow in the lowlands and highlands with an altitude between 0-900 m asl. It indicates that shallots have the potential to be planted in Entisol and Inceptisol soils. However, shallots require soils with good drainage and aeration, organic matter, and slightly acidic to normal pH. Thus, it is necessary to improve the properties of Entisols and Inceptisols (Syawal et al., 2019). Increasing the efficiency of fertilization can be done, among others, by improving fertilization application techniques and improving the physical and chemical properties of fertilizers through changes in the nutrient solubility system, shape and size of fertilizers, and formulations of fertilizer nutrient levels.

Nano-fertilizers that are very small (1 nm = 10^{-9} μm) have more reactive properties, which can directly hit the target, and their use only requires small amounts. The ball milling method is a method that is often used to grind the powder to a nanometer scale. Its working principle depends on the energy released due to friction between the ball, the powder, and the operating time. The longer the friction occurs, the finer the particles are produced (Piras et al., 2019). In addition, one way to increase the efficiency of fertilization is to modify the fertilizer into a slow-release fertilizer so that the nutrients contained in the fertilizer can be released gradually according to the time needed by the plant. Coating nanomaterials in fertilizers can slow the release of nutrients in the fertilizer.

Rugayah et al., (2018) mentioned that slow-release fertilizer (SRF) was a mechanism for releasing nutrients gradually, following the pattern of nutrient absorption by plants, thereby leading to optimal fertilizer absorption by plants. One way to modify fertilizers into slow release is to mix fertilizers and materials with a high cation exchange capacity, such as zeolites (Dubey & Mailapalli, 2019). Zeolite is a hollow silicate mineral with a high cation exchange capacity so that it can exchange cations. Crab shells can also manufacture slow-release fertilizers because they have pores that can hold nutrients. Zeolite and crab shells can be made nano-sized and then encapsulate fertilizers to become slow-released. According to Noviyanita (2018), increasing the dose of inorganic fertilizers can increase the production of shallots. Hartatik et al., (2020) stated that zeolites could play a role in the gradual release of nutrients. Zeolite that has undergone a change in size to nano is able to increase the efficiency and effectiveness of fertilization on plants because it releases nutrients slowly and is able to reduce fertilizer doses (Lateef et al., 2016). The chitin content in crab shells can be used as an adsorbent to adsorb phosphate, so that crab shells are expected to be able to absorb nutrients in fertilizers, such as nitrogen and potassium, which can then be rereleased for plants.

This research was carried out by converting zeolite and crab shells into nano size with a ball mill, which were then used to encapsulate NK fertilizers to improve their effectiveness. Fertilizer application was given to shallots in Entisol and

Inceptisol soils. Urea and KCL are water-soluble fertilizers, so they will easily leach out from the plant root zone when applied to sandy soil. Those causes the low agronomic efficiency of these two types of fertilizers. Therefore, encapsulation technology is needed to engineer the two fertilizers into slow-release fertilizers. Materials such as zeolite and crab shells are widely available and inexpensive, so they are prospective enough to be used as nano-materials. This study aimed to compare the agronomic effectiveness of NK-SRF encapsulated with nano-zeolite and nano-crab on Shallots in Entisols and Inceptisols.

MATERIALS AND METHODS

Experimental Design

This research was conducted in the experimental field and Soil Laboratory from September 2020 to February 2021. This research was arranged in a completely randomized design with three treatment factors. The first factor was the types of soils, consisting of Entisol and Inceptisol, the second was the types of nano material, including nano zeolite and nano crab shell, and the third was the doses of NK, which were125:50, 250:100, 375:150, and 500:200. Each treatment was replicated three times. Soil preparation was carried out by taking Entisol soil from Kulon Progo (7.9^{0}67.3'34.9"S 110.18^{0}18.2'60.7"E) and Inceptisol from Gunung Kidul (7^{0}52'20.6"S 110^{0}31'35.1"E) in the tillage layer at a depth of 1-20 cm.

Research Methods

Material preparation was carried out by preparing urea-KCl fertilizer, zeolite, and crab shells. Zeolite and crab shells were cleaned and then mashed to a size of 100 mesh. Fertilizer was manufactured by making zeolite and crab shells into nano size using a ball mill, with a ratio of steel balls, zeolite/crab shells, and water of 500 g: 100 g: 60 ml, respectively. The milling process was carried out for six hours. The principle of milling is grinding the materials on the surface of balls due to colliding with other balls. The manufacture of nanomaterials is successful if 70% or more of the particles have a size of 1-100 nm (Khan et al., 2019). The formulation was carried out by mixing urea and KCl with nano zeolite and nano crab shells according to treatment in a ratio of 6:1 (Kottegoda et al., 2017). Mixing was done conventionally using centrifugal force.

The planting media was prepared by taking samples of Entisol soil from Kulon Progo beach sand and Inceptisol soil from the tillage layer at a depth of 1-20 cm. The soil was air-dried, sifted, cleaned from dirt and weeds, and then put into polybags according to the volume of polybags 28.260 dm^3/0.28 L. Entisol soil was obtained from Kulon Progo beach sand, and Inceptisol soil was obtained from Karangsari, Gunung Kidul. Planting was done by immersing all shallot seeds in the soil. The seeds used have previously gone through a shelf life of ±3 months and then cut 1/3 of the ends to break dormancy so that the growth is uniform. The treatments were applied after basic fertilization (cow manure 20 tons/ha and SP-36 90 kg/ha incubated for 7 days). Harvesting was done when the shallot plants had fallen 50% and turned yellow (55 days after planting).

Variables Observation

The variables observed were soil physical and chemical properties, characterization of nanoparticles, plant height, number of leaves, bulb diameter, shoot fresh and dry weight, root fresh and dry weight, and bulb fresh and dry weight. Soil physical and chemical properties include soil texture, pH, organic C, organic matter, total N, available P, avaible K, CEC, Ca, Mg, Na, and base saturation. Soil physical and chemical properties of incubated soils were analyzed in the laboratory. Plant height and diameter of bulbs were measured every week, while shoot fresh and dry weight, root fresh and dry weight, and bulb fresh and dry weight were measured after the harvest. Fresh weight was the weight after harvest. Dry weight was obtained after the samples were dried in the oven at a temperature of 65^{0}C for 3-4 days.

Data Analysis

The data collected were analyzed using ANOVA and continued with Tukey's test (HSD) using SAS program to find out the significant differences between treatments. Data from the characterization of nano particles were analyzed using Scanning Electron Microscopy (SEM) followed by analysis using image-J to find out the size of nano particles and the element content of nano particles. The agronomic efficiency was calculated by the formula as follows:

$$AE\ (\%) = \frac{(Y\text{-}Y0)x100\%}{F} \quad (1)$$

Where, Y = yield of harvested portion of crop with nutrient applied; Y0 = yield without nutrient application; F = amount of nutrient applied.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties

Based on Table 1, the texture of entisol soil before incubation is categorized as sand with a slightly alkaline pH. The organic C, total N, and available P contents are low, extremely low, and low, respectively. Soils are poor in P minerals, and the management level is still not intensive. Cation exchange capacity (CEC) is low, as well as the levels of Ca, Mg, and Na are categorized as very low to low ratings. Gunawan et al., (2019) stated that the soil cation exchange capacity (CEC) affects the availability of cations such as Ca, Mg and Na in the soil, if the soil CEC is low, the availability of these cations is also low. This is because base saturation is often directly proportional to cation exchange capacity (CEC) because it illustrates the level of cations present in the soil. The analysis results follow Sutardi (2017), stating that entisols have a sand texture, granular soil structure, loose consistency, and are very porous so they have low water and fertilizer buffering capacity. The content of organic matter and total N is also relatively low. The available K contained in the entisol is relatively high, related to the soil pH. According to Gunawan et al., (2019), an acidic pH can cause an increase in potassium fixation, resulting in a decrease in the availability of K in the soil.

Based on Table 1, Inceptisol has a silt loam texture and an acidic pH. The organic C, total N, and available P contents are low, very high, and moderate, respectively. Meanwhile, the cation exchange capacity (CEC) is moderate and directly proportional to cations such as Ca, Na, Mg, and K, which are classified as extremely low, medium, medium, and low, respectively. The cation exchange capacity (CEC) and the low number of base cations make the base saturation of the Inceptisol extremely low. The analysis results were supported by Sudirja et al., (2017), stating that in general, Inceptisols have an acidic pH and high clay content, and the surface layer is easily washed so that it is easy to lose nutrients. The Inceptisol soil of Karangsari, Gunung Kidul is dominated by the silt fraction and has a very high available N content.

Nano Material Characteristics

Table 2 presents the particle size distribution of the zeolite obtained after pounding with steel balls for 6 hours. The proportions of particle sizes are as follows: 1-10, 10-20, 20-100, 100-250, 250-1000, and > 1000 nm, each of which has a percentage of 35.61, 24.09, 31.71, 6 .19, 2.40 and

Table 1. Physical and chemical properties of Entisols and Inceptisols

No.	Parameter	Entisol	Inceptisol
1	Texture (USDA)	Sand	Loam
	Sand (%)	91.94[S]	33.43[SL]
	Silt (%)	4.48[S]	57.63[SL]
	Clay (%)	3.58[S]	8.94[SL]
2	pH-H_2O (1:5)	7.95[SA]	5.2[A]
3	pH-KCl (1:5)	7.70	5.1
4	Organic C (%)	0.33[L]	1.27[L]
5	Organic matter (%)	0.56	2.19
6	Total N (%)	0.91[EH]	1.18[EH]
7	Available P (mg kg^{-1})	7.07[L]	10.92[M]
8	Available K (cmol(+)kg^{-1})	0.95[H]	0.21[L]
9	CEC (cmol(-)kg^{-1})	12.43[L]	19.95[M]
10	Available Ca(cmol(+)kg^{-1})	0.62[EL]	1.13[EL]
11	Available Mg (cmol(+)kg^{-1})	0.11[EL]	1.98[M]
12	Available Na (cmol(+)kg^{-1})	0.32[L]	0.40[M]
13	Base Saturation (%)	16.04[EL]	18.68[EL]

Remarks: S=sand, SL=silt loam, SA=slightly alkaline, A=acid, L=low, EL=extremely low, M=medium, H=high, EH=extremely high

0.02%. The total percentage of zeolite size that can be categorized as nano particles (<100 nm) is 91.41%. While the particle size distribution of crab shells are: 10-20, 20-100, 100-250, 250-1000, and > 1000 nm with each percentage 52.85, 44.72, 1.68%, 0.71 and 0.02%. The percentage of total particle size of crab shells that can be categorized as nanoparticles (<100 nm) is 97.50%. The best size of materials for plants is 1-100 nm. The splitting of the particles into nano size is thought to be caused by the collision between the particles and the steel ball for 6 hours. This is in line with Subramanian et al., (2015), mentioning that the synthesis of nanoparticles using a physical approach, especially milling using high-energy ball milling can make the particle size into nano. Milling for 1, 2, 4, and 6 hours reduced the particle size to 1078, 475, 398, and 203 respectively. The reduction in size resulted in an increase in the surface area to 41, 55, 72, 83, and 110 $m^2g^{1,}$ respectively.

The highest elemental content in nano zeolite is O, with 56.82%, and Si, with 30.71%, while the lowest element content is Mg, which is 0.62%. This is in line with Estiaty (2015) research results, reporting that the main composition of zeolite is dominated by Si 72.3% and Al 10.68%. In addition, there are also cations such as Na, K, Ca, and Mg, which function as a counterweight to the negative charge originating from Si and Al filling the center of the tetrahedron of four oxygen atoms. The highest elemental content in nano crab shells is O, 46.02%, and Ca, 28.01%. Meanwhile, the lowest element content is K, which is 0.06%. This is in line that Ca is the highest elemental content found in crab shells, which is 14.96%. The main content in crab shells are calcium and magnesium carbonate, chitin, and some proteins. Handayani et al., (2019) stated that crab shells contained high Ca, which could be identified early by the hard-shell shape.

Table 2. Particle size of Nano Materials

Diameter (nm)	Nano Zeolite		Nano Crab shell	
	Total	%	Total	%
1-10	1669	35.61	0	0
10-20	1129	24.09	2448	52.86
20-100	1486	31.71	2071	44.72
100-250	290	6.19	78	1.68
250-1000	112	2.40	33	0.71
>1000	1	0.02	1	0.02
	Mean = 39.78 nm		Mean = 30.84 nm	

Table 3. Effect of treatments on agronomic traits

Treatments	Plant Height (cm)	Leaf Number	Bulp Number	Bulp Diameter (cm)	Shoot Fresh Weight (g)	Shoot Dry Weight (g)	Root Fresh Weight (g)	Root Dry Weight (g)	Bulb Fresh Weight (g)	Bulb Dry Weight (g)	Yield (kg/ha)
Soil Types											
Entisol	21.75 b	15.47 b	8.45 b	11.21 b	6.29 b	0.47 b	1.70 b	0.12 b	11.97 b	1.44 b	1685 b
Inceptisol	28.37 a	24.93 a	12.97 a	17.35 a	20.27 a	1.42 a	3.09 a	0.41 a	38.70 a	1.80 a	5450 a
Nano Materials											
Zeolite	24.98 p	22.20 p	10.97 p	14.44 p	13.72 p	0.99 p	2.13 x	0.22 x	24.80 p	1.56 p	3490 p
Crab Shell	25.14 p	18.20 q	10.45 p	14.12 p	12.69 p	0.90 p	2.66 x	0.31 x	25.90 p	1.67 p	3636 p
NK doses											
0 (blanko)	24.55 x	17.58 x	8.97 x	10.69 y	8.35 x	0.68 x	1.28 x	0.15 x	17.80 y	1.31 x	2506 y
125:50	27.67 x	18.00 x	10.75 x	15.81 x	14.08 x	0.96 xy	2.26 x	0.21 x	28.73 x	1.61 x	4046 x
250:100	24.32 x	20.58 x	12 x	14.85 x	15.78 x	1.14 x	3.155 x	0.35 x	30.57 x	1.81 x	4305
375:150	24.75 x	22.67 x	10.67 x	15.15 x	13.96 x	0.09 xy	2.70 x	0.34 x	23 xy	1.67 x	3238xy
500:200	24.01 x	22.17 x	11.17 x	14.90 x	13.87 x	1.03 xy	2.59 x	0.28 x	26.60 xy	1.68x	3745xy
Soil> <Nano> <NK dose	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
CV (%)	21.24	36.66	31.12	14.87	24.58	37.37	30.78	14.73	34.45	43.99	34.46

Plant Height (cm)

Based on Figure 1, there was an increase in plant height from the first week to the seventh week. The decrease in plant height at week 8 was caused by the plant starting to fall. Shallot plants ready to be harvested have the characteristics of a yellowing crown, and the plant begins to fall. The combination of treatments with the highest average plant height was the treatment of shallots grown in Inceptisol soil using nano crab shell coated fertilizer with a dose of 125:50 (Table 1). The best shallots height reached 35 cm, according to the height of shallots in general between 1-50 cm depending on the variety. This treatment had a better plant height than the conventional treatment, producing a plant height of less than 30 cm. This is thought to be caused by nano fertilizer with the right dose, which can increase Inceptisol's ability to increase the growth of shallot plants. Khan et al., (2021) we propose macronutrients incorporated slow-release based nano-fertilizer using nanozeolite as a carrier. A simple chemical approach was used

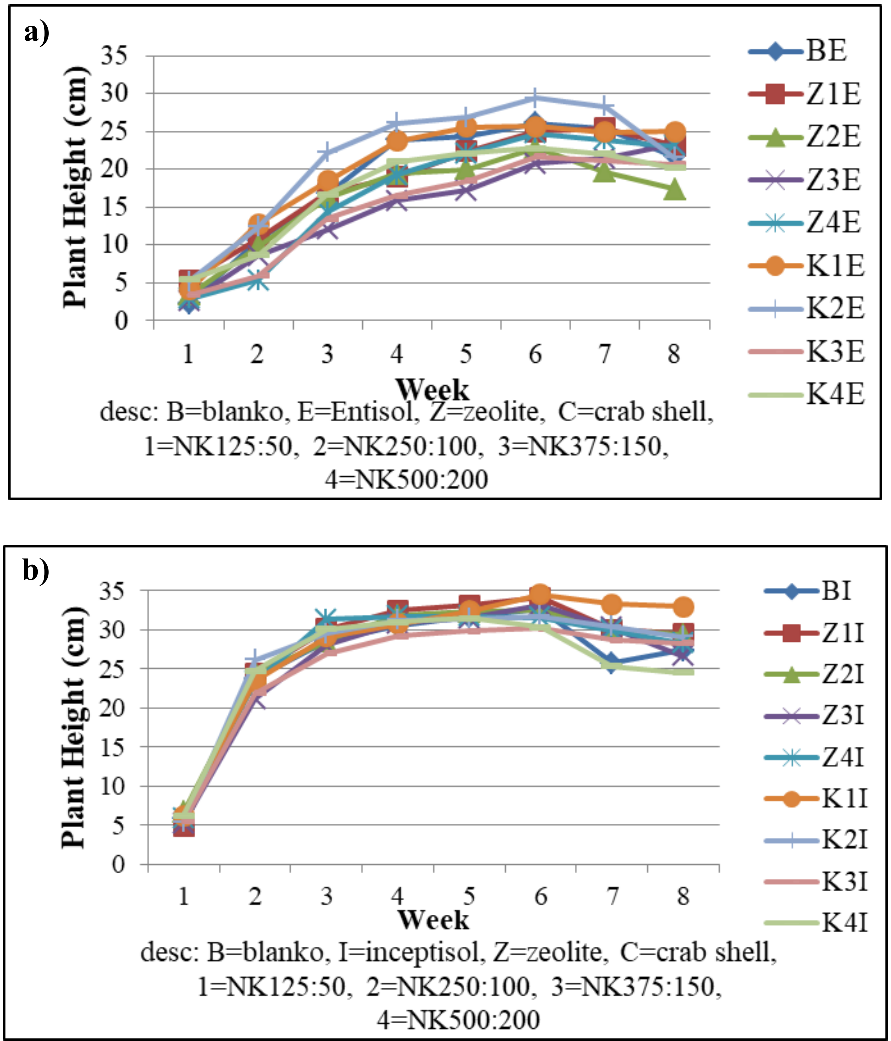

Figure 1. Plant Height as affected by NK-Z and NK-C in (a) Entisols and (b) Inceptisols

to synthesis the proposed nanozeolite composite fertilizer (NZCF) stated that nano fertilizer was a nano-sized fertilizer containing nanoparticles and nutrient encapsulation, capable of releasing micro and macronutrients targeted at plants. Nanomaterials can be used to hold nutrients for plants for a long time.

Number of Leaves

Based on Table 1, each treatment did not show significant results. Based on Figure 2, the combination of Inceptisol soil treatment with nano zeolite coated fertilizer at a dose of 125:50 had the highest average number of leaves. The number of leaves for each treatment increased every week. However, there was a decrease in the number of leaves in the last week. The shallot that is ready to be harvested begins to fall, and the leaves turn yellow until they are almost wilted. The highest number of leaves was observed in the combination of Inceptisol treatment and zeolite coated fertilizer at a dose of 125:50 (Table 1), proving that nano fertilizers can increase plant growth by controlling the release of nutrients so that they are available according to to plant needs. The highest number of leaves reached 45 strands; this treatment was better than the conventional treatment, producing less than 30 leaves. In general, nano zeolite has advantages compared

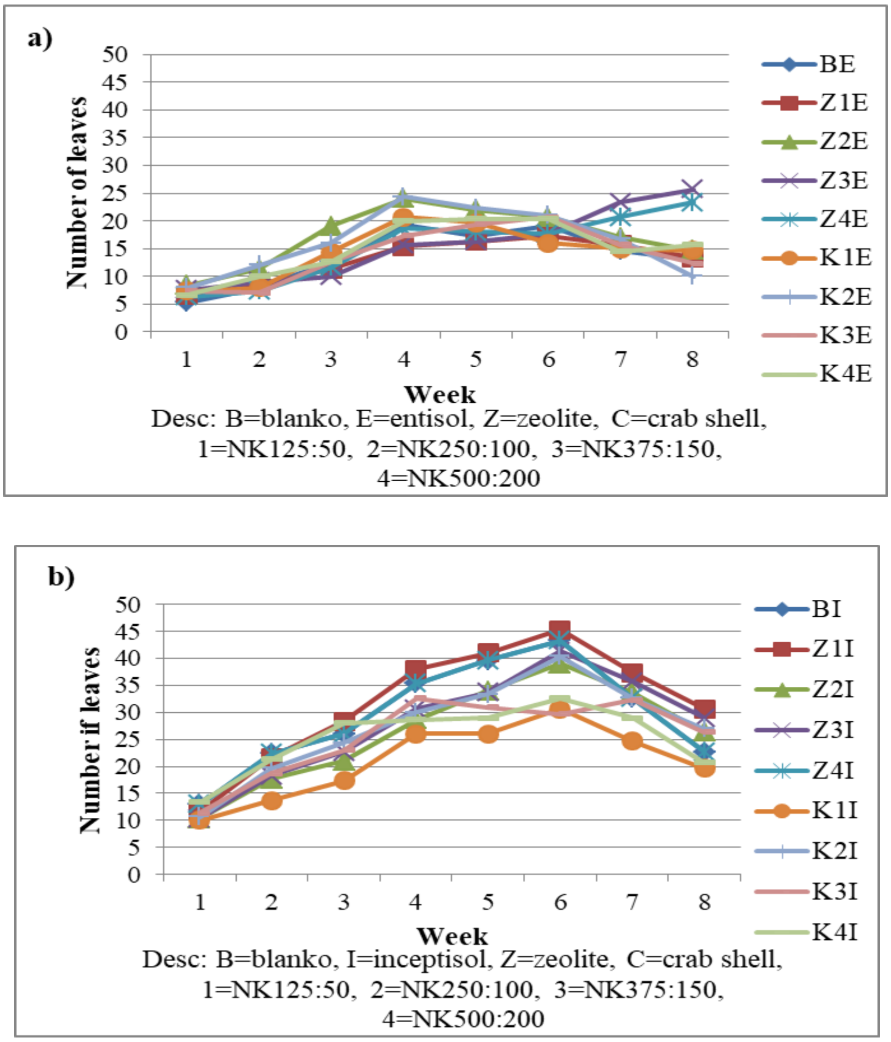

Figure 2. Number of leaves as affected by NK-Z and NK-C in (a) Entisols and (b) Inceptisols

to zeolite. Zeolite modified to nano size has a high surface area, mesoporous structure, and higher nutrient loading capacity. Using nanomaterials in slow-release fertilizers can increase the nutrient retention capacity of the soil (Khan et al., 2021).

Number of Bulbs

Based on Table 1, the highest average number of bulbs was found in the combination of Inceptisol treatment and nano zeolite coated fertilizer at a dose of 250:100. The highest number of bulbs reached 15 bulbs, and this treatment was better compared to the conventional treatment, which produced less than 6-7 bulbs. This proves that the use of nano zeolite as a coating can affect the yield of shallots. Coatings using nanomaterials can control nutrient output so that nutrients remain available according to plant needs during the planting period. The research results of Khan et al., (2021) also showed that using nano zeolite fertilizers could improve the soil's physical, chemical, and biological properties to increase plant growth and yield. Nano zeolite can release nutrients for a longer period when compared to conventional fertilizers, thereby reducing nutrient leaching (Lateef et al., 2016).

The average number of bulbs in Inceptisol was better than in Entisol, proving that Inceptisol had more favorable physical and chemical properties

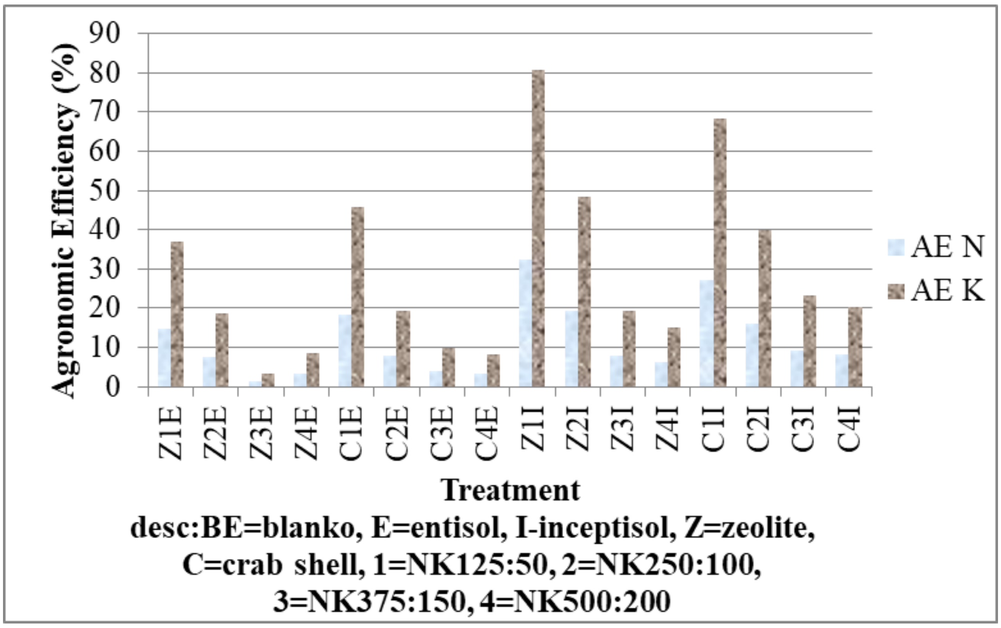

Figure 3. Agronomic Efficiency of NK-Z and NK-C

for plants. Fertilization at the appropriate dose can improve the physical and chemical properties of the soil. Napitulu & Winarto (2010) stated that the use of N fertilizer at a dose of 250 kg/ha and K fertilizer at 100 kg/ha was estimated to be able to increase the quantity and quality of shallot crop yields.

Bulb Diameter (mm)

Based on Table 1, the highest value of bulb diameter was found in the combination of Inceptisol treatment and nano zeolite coated fertilizer at a dose of 125:50. The highest value of bulb diameter reached 19 mm, and this treatment was better compared to the conventional treatment, which produced bulb diameter of less than 6 mm. This result shows that nano zeolite can control the nutrient output according to the plant's needs during the growing period. Yuvaraj & Subramanian (2018) mentioned that modification of fertilizer with nano zeolite could reduce fertilizer loss due to evaporation and leaching. Zeolites could retain nutrients in the root zone, which could be released according to plant needs.

Shoot Fresh Weight (g)

The combination of Inceptisol treatment and nano zeolite coated fertilizer at a dose of 250:100 had the highest average fresh weight of shoots compared to other treatments (Table 1). The highest shoot fresh weight reached 29 g, which was better than the conventional treatment, producing a fresh shoot weight of less than 6 g. Nano zeolite can control the release of nutrients properly to fit the needs of plants. Based on the analysis of the physical and chemical properties of the soil, Inceptisol has more favorable properties for plant growth and development than Entisol. The change of particles to nano size can increase the surface area and the number of pores to increase the ability to hold nutrients. The surface area of zeolite can be increased by ball milling. Ball milling is a top-down approach to reduce the size of the zeolite so as to increase absorption. Cations such as NH^{4+} and K^{+} can be adsorbed and desorbed slowly according to plant needs. Nano zeolite has a negative charge that is able to absorb cations and then release them regularly and stably. This process will produce nano fertilizer formulations that help regulate the release of nutrients, increase fertilization efficiency, and prevent environmental harm (Yuvaraj and Subramanian, 2018).

The elements N and K are very important in plant growth and yield. The research results by Napitulu & Winarto (2010) showed that applying N fertilizer at a dose of 250 kg/ha and K fertilizer at a dose of 100 kg/ha could increase the growth and yield of shallots.

Shoot Dry Weight (g)

The combination of Inceptisol treatment and nano zeolite coated fertilizer at a dose of 250:100 had a higher average shoot dry weight compared to other treatments (Table 1). The highest shoot dry weight reached 1.82 g, and this treatment was better compared to the conventional treatment, which produced shoot dry weight of less than 0.45 g. The shoot dry weight is related to the fresh shoot weight, in which the dry shoot weight shows the absolute weight of the plant canopy. In harmony with the fresh shoot weight, the average shoot dry weight in the treatment combination proved that the nutrients were well absorbed, thereby increasing the yield of shallots. The use of nano zeolite as a fertilizer coating was proven to be able to provide plant nutrient needs during the growing period.

Root Fresh Weight (g)

The highest fresh root weight was found in the combination of Inceptisol treatment using nano crab shell coated fertilizer at a dose of 375:150. The highest root fresh weight reached 5.56 g, which was better than the conventional treatment, producing a fresh root weight of less than 1.20 g. This is thought to be caused by the influence of crab shells as a coating, which is able to hold nutrients so they are not released directly into the environment. In addition, crab shells can chelate metals in the soil to prevent interactions between metals and nutrients, such as P and K, so that nutrients can be available to plants. The higher the dose of fertilizer given to plants, the more nano crab shells were given. This then increases the availability of nutrients in the soil and increases nutrient uptake by plant roots (Rais et al., 2017).

Root Dry Weight (g)

The combination of Inceptisol treatment and nano crab shell coated fertilizer at a dose of 375:150 had maximum root dry weight compared to other treatments (Table 1). The highest root dry weight reached 0.88 g, and this treatment was better compared to the conventional treatment, which produced root dry weight of less than 0.12 g. In accordance with the fresh weight of the roots, the combination of treatments with the highest dry weight of roots proved that the highest accumulation of organic compounds in the roots was found in the combination of Inceptisol and nano crab shell coated fertilizer at a dose of 375:150. Modifying crab shells into nano size can also increase the surface area and pore density so that it can hold nutrients and is not easily released into the environment. In addition, based on the analysis of the elemental content contained in crab shells, it shows that crab shells contain elements such as Ca, C, and Na, which can increase plant growth and yield.

Bulb Fresh Weight (g)

The highest value of fresh bulb weight was found in the combination of Inceptisol and nano zeolite coated fertilizer at a dose of 250:100 (Table 1). The maximum bulb fresh weight reached 49.78 g, and this treatment was better compared to the conventional treatment, which produced bulb fresh weight of less than 9.31 g. In addition to affecting plant growth, the use of nano zeolite coated fertilizer also affects the yield of shallots.

The quality of the bulb is related to the formation of the canopy. N element helps in the formation of the canopy, and the K element helps the process of translocation of photosynthate products to be better so that the quality of the bulb produced is also better (Prasetya et al., 2015). Zeolite formulation into nano fertilizer can increase the efficiency of N and K fertilization in plants. The slow release of nutrients is able to provide nutrients during the growing period according to the period needed by the plant.

Bulb Dry Weight (g)

Based on Table 1, the combination of Inceptisol and nano zeolite coated fertilizer at a dose of 250:100 had higher bulb dry weight compared to other treatments. The highest bulb dry weight reached 8.95 g, and this treatment was better compared to the conventional treatment, which produced bulb dry weight of less than 1.36 g. Bulb dry weight is the absolute weight of the tubers, which is also related to the bulb fresh weight. The combination of treatments with the highest bulb dry weight was in line with the combination of treatments with the highest bulb fresh weight (Table 1). Fertilization can improve the quality of Inceptisol's physical and chemical properties, which are beneficial for plants. Modification of zeolite into nano size was also proven to be able to increase the ability of zeolite to hold nutrients better than the previous size so as to control the release of nutrients better as well.

Agronomic Efficiency (%)

Based on Figure 3, the best agronomic effectivity value was found in the combination of Inceptisol and fertilizer coated with nano zeolite at a dose of 125:50. This result proves that nano zeolite is able to hold nutrients well and release it according to plant needs during the growing period. Crop yields influence agronomic efficiency. Inceptisols were proven to have more favorable soil physical and chemical properties for the growth and yield of shallots compared to Entisols. Application of fertilizer that has been coated using zeolite allows nutrient output to be well controlled. Yuvaraj & Subramanian (2020) stated that fertilizers coated with nanomaterials could increase nutrient absorption, increase soil fertility, and reduce fertilizer toxicity. Nano zeolite is able to carry nitrogen, phosphorus, potassium, and micronutrients in fertilizers so as to increase plant productivity. The use of zeolite in nano-tech fertilizers can provide nutrients to plants for 50 days. This shows that nano zeolite coated fertilizer is able to provide nutrients longer than conventional fertilizers, which can provide nutrients only for 10-12 days. The best result, which is at a dose of 125:50, is in line with the research of Napitulu & Winarto (2010), stating that N at a dose pf 250 kg/ha and K at a dose of 100 kg/ha gave the best results on uncoated shallots, thus allowing the use of smaller doses of fertilizers with coatings.

CONCLUSIONS

Treatments of soil types, encapsulation materials, and doses of NK fertilizer did not significantly affect the agronomic traits of shallot plants. These plants grew well and produced better yields in inceptisols than in entisols. The types of encapsulation material and NK doses had no significant effect. Although not statistically significant, the shallot yield produced by nano crab shell coated NK treatment was better than that produced by nano zeolite coated NK. NK doses with a ratio of 125:50 and 250:100 obtained the highest yields, but the highest agronomic efficiency (EA) was obtained in nano zeolite coated NK at a dose of 125:50.

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