Original Research Article

THE ROLE OF ZEOLITE AND NPK PONSKA FERTILIZER ON MAIZE (*Zea mays* L.) GROWTH IN INCEPTISOL, SOUTHERN SOLOK DISTRICT

ABSTRACT

The research objective was to determine the role of zeolite in increasing the efficiency of NPK PONSKA fertilizer on the growth and yield of maize in Inceptisol Southern Solok. This research was conducted in July - November 2022, in Jorong Bukit Malintang Barat Nagari Lubuk Gadang, Sangir District, South Solok Regency, with an elevation of 998 m above sea level, the soil type is Inceptisol, with a soil pH of 5.76, belonging to the slightly acidic. The experiment was arranged in a randomized block design with a factorial arrangement of treatments in 2 treatment factors. The 1st factor was the dose of zeolite from 0, 100 and 200 kg ha^{-1}, the 2nd factor was PONSKA NPK fertilizer (15-15-15) with a dose of; 100, 200, and 300 kg ha^{-1}, arranged in 3 blocks. The data obtained was analyzed using the F test with a significance level of 5%, and then using the DNMRT follow-up test with a significance level of 5%. The parameters; soil pH, plant height, leaf area index, weight of 100 maize kernels, moisture content of 14%; and yield per hectare. The data obtained were presented in the form of tables and figures, establishing the interaction relationship between the two treatments in the form of graphs. The resulted was giving 100 kg ha^{-1} NPK PONSKA was able to provide optimal NPK nutrient uptake, plant height and LAI at 54 DAP. The combination of 100 kg ha^{-1} zeolite and 200 kg ha^{-1} NPK PONSKA provided optimal yields of dry shelled maize reaching 5.44 tonnes ha^{-1}.

Keywords: NPK PONSKA Fertilzer; Zeolite; Maize; Inceptisols

1. INTRODUCTION

Southern Solok is one of the maize centers in West Sumatra. This location is at an altitude of 350–430 meters above sea level. Its area reaches 359,013 ha, consisting of 150,532 ha protected forest area (41.93%) and 208,481 ha (58.07%) cultivation area. The landscape varies between lowlands, hills, and highlands which are a series of the Bukit Barisan mountains (1). Location of research activities on Inceptisol. This soil type can be categorized as newly developing soil, due to the discovery of the B horizon, cambic. The cambic horizon is a newly formed B horizon as a result of the development of the soil. The fertility of Inceptisols is largely determined by the geology and parent material that makes up the soil. The Inceptisol of southern Solok has low to moderate fertility (2). The farmers in Southern Solok Regency, West Sumatra, admitted that their yields of maize have reduced due to the difficulty in obtaining subsidized fertilizer during the planting season.

Southtern Solok Regency has abundant natural resources. Extensive land has been developed, making the agricultural and plantation sectors the largest contributor to the community's economy. The Gross Regional Domestic Product of the agricultural sector at constant prices is the highest in 2020 at 1,172,982.23 (3). Based on the GRDP value in 2021 the agricultural sector was 1,212,848.70 and every year this agricultural sector has increased. However, in 2021 the agricultural sector in southern Solok will experience a decline. However, the agricultural sector is still the highest contributor or it can be said that the agricultural sector is the leading sector in South Solok Regency. South Solok maize yield was 95,210.56 tons, and this commodity was more dominant in South Solok than in West Sumatra (4).

However, the high maize production must also be balanced with high fertilizer availability. The problem was that the price of fertilizer had also increased significantly. Therefore, it is difficult for farmers to provide optimal fertilization for maize cultivation in Southern Solok. Several studies have proven that the use of zeolite as a soil amendment is considered to be able to use artificial fertilizers efficiently. (5) told that zeolites, due to their unique properties are a subject of an ongoing scientific research for applications as adsorbents and ion exchangers in numerous areas of agriculture and environmental protection. (6) determined that zeolites are great tools to help the farmer and agronomist cope with several issues, such as soil or water pollution, contamination by heavy metals, loss of nutrients, and loss of water-use efficiency (WUE) of drylands. These natural crystalline aluminosilicates are considered soil conditioners to improve soil chemical and physical properties, such as saturated hydraulic conductivity (*Ks*), infiltration rate, cation exchange capacity (CEC), and water-holding capacity (WHC). (4) demonstrated that 300 kg ha^{-1} zeolite can reduce fertilizer use by around 20% P in paddy rice plants. The same thing applies to K fertilizer in Planosols such as in Jakenan. Zeolite plus which has been enriched with a number of nutrients gives better performance than zeolite without added nutrients. Application of zeolite plus high doses (5-10 tonnes ha^{-1}) to increase soil CEC, in greenhouse conditions can give MPD yields of around 11.9 tonnes ha^{-1}. Likewise (Arafat et al., 2016) established that applying zeolite 9.3 tonnes ha^{-1} with a combination of 150 kg ha^{-1} SP-36 fertilizer increased P fertilization efficiency by 65%. The use of 9.3 tonnes ha^{-1} zeolite and 150 kg ha^{-1} SP-36 fertilizer showed an increase in plant height of 34.8%, an increase in plant wet weight of 95.7%; and an increase in plant dry weight by 98%. This increase showed that zeolite had an effect on increasing P uptake and growth of sweet maize. The research objective was to determine the role of zeolite in increasing the efficiency of NPK PONSKA fertilizer on the growth and yield of maize in Inceptisol Southern Solok.

2. MATERIAL AND METHODS

This research was conducted in July - November 2022, in, Sangir District, Southern Solok Regency, with an elevation of 998 m above sea level, the soil type is Inceptisol, with a soil pH of 5.76, belonging to the slightly acidic category. The maize plants tested were the superior varieties of Pioneer P32 hybrids. (7) explained that P32 hybrid maize is maize that has upright stems, is strong and does not collapse easily. Yields reach 13.4 tonnes per hectare of dry shells, with a low moisture content that makes them resistant to cob rot. The P32 hybrid maize seeds are bright red in color and contain good protein, making them suitable for animal feed.

The experiment was arranged in a randomized block design with a factorial arrangement of treatments in 2 treatment factors. The 1st factor was the dose of zeolite (112.57 cmol kg^{-1}, 51.71% SiO2; 9.49% water content), from 0.100 and 200 kg ha^{-1}. The 2nd factor was PONSKA NPK fertilizer (15-15-15) with a dose of; 100, 200, and 300 kg ha^{-1}, arranged in 3 blocks. The NPK PONSKA Fertilizer that was given was mixed first with the Zeolite which was applied entirely when the plants were 7 DAP. (8) recommended that the data obtained was analyzed using the F test with a significance level of 5%, and then using the DNMRT follow-up test with a significance level of 5%. The parameters were observed; plant height, leaf area index, weight of 100 maize kernels, moisture content of 14%; and dry-shelled weight per hectare. Soil chemical analysis was carried out as a preliminary soil analysis by observing several nutrients and soil physical properties, following the instructions (9). The data obtained were presented in the form of tables and figures, establishing the interaction relationship between the two treatments in the form of graphs.

The implementation of this research started with soil processing and preparation of seeds and fertilizers. The plots were arranged according to the experimental design with a size of 2 x 3 m in 27 experimental plots, with maize planted in a row legowo pattern (2:1) with spacing (50 cm x 20 cm), a plant population of 40 stems per plot. the maize seeds were treated using Ridhomil to prevent downy mildew, then planted 2 seeds per hole. one week later selected which maintained only 1 plant per planting point.

The NPK and zeolite fertilizers are given together with pre-application treatment, NPK and Zeolite fertilizers are stirred together and then aged for 6 hours to make effective use of the zeolite, and the maize plants are maintained until harvest. The test was carried out at the Central Horticulture Seed Center at the Southern Solok Regency Agriculture Office with a pH of 5.1. Observations include; plant height, maize leaf area index, N, P, and K nutrient uptake of maize plants, and maize dry-shelled yield. Determination of N, P, and K nutrient absorption was carried out at the end of the vegetative phase of the maize plant by harvesting all the tops of the maize plant and then drying it in an oven at 70^0C for 48 hours. The dried plants were then crushed using a grinder and then analyzed using the wet incineration method. P and K measurements used a spectrophotometer while the determination of N-total used the Kjeldahl method (10). Soil pH was determined with a pH meter electrode by setting a ratio of soil and water samples of 1:2.5.

3. RESULTS

3.1 Initial soil chemical properties and Soil pH at Flower Primordial

The results of preliminary soil chemical analysis have been carried out to get an illustration that the fertility of the soil used for this study was low, this is indicated by a very low base saturation rate, even though the value of the soil cation exchange capacity was high. In Table 1, the results of the initial soil analysis are presented;

Table 1. Results of soil chemical analysis before planting in Sangir District, Southtern Solok Regency

No	**The elements**	unit	results	Criteria*)$^{*)}$(10)
1.	pH (H2O)		5,76	Rather acid
2.	pH (KCl)		5,63	
3.	Total-N	%	0,699	high
4.	P available (Bray 2)	ppm	4,683	row
5.	Exchangeable-K	cmol kg^{-1}	0,308	low
6.	Exchangeable-Na	cmol kg^{-1}	0,262	low
7.	Exchangeable-Ca	cmol kg^{-1}	0,425	Very low
8.	Exchangeable-Mg	cmol kg^{-1}	1,159	moderate
9.	CEC	cmol kg^{-1}	31,20	high
10.	Base Saturation	%	6,904	Very low
11.	Organic-C	%	10,733	Very high
12.	C/N		15,355	

The soil base saturation was very low, indicating that the availability of nutrients in the form of basic cations is very low and results in plants experiencing deficiency of these elements. Some of the nutrients classified as bases have low availability, among others; Mg, K, Na, and Ca ions. All of these elements are cations which are important for plants to form vegetative, generative parts and activate several enzymes that play a role in biochemical reactions in plants. Because of these soil chemical conditions, it is important to apply fertilization and include the application of soil amendments such as zeollite. Especially for maize cultivation also requires sufficient availability of Ca and Mg. In addition, low P elements are also in the soil, requiring efforts to apply fertilizers containing P to be in accordance with plant needs. Element P in maize plants is needed to produce ATP which is useful as an energy reserve for plants to carry out metabolism so that plants can grow normally according to the age of the plant.

Changes in soil pH due to flower primordial treatment are presented in Table 2. The application of NPK PONSKA and Zeolite did not affect the soil pH. This is because the two materials applied to the soil do not significantly increase or decrease soil pH. The results indicated that analysis of NPK Phonska fertilizer, was actually rather acidic, with a pH range of 5-6. However, because NPK fertilizer was also accompanied with zeolite, the pH does not decrease significantly, because zeolite plays a role in increasing soil CEC so that it can absorb H^+ ions which will cause soil acidity.

Table 2. Soil pH affected by Zeolite and NPK Phonska

Zeolite dose	PONSKA Dose (kg ha^{-1})			
(kg ha^{-1})	100	200	300	average
	--pH---			
0	5.86	5.76	5.80	5.81
100	6.00	5.73	5.86	5.86
200	5.83	5.76	6.00	5.86
average	5.90	5.75	5.88	
CC (%)	9.53			

3.3 The N, P and K uptake of maize plants at 54 Days after Planting (DAP)

The application of Zeolite and Phonska NPK significantly interacted with the transport of N, P, and K nutrients in maize plants, presented in Table 3. If the maize plants receive 100 kg ha^{-1} of Phonska NPK, then increasing the dose of Zeolite will significantly increase the uptake of N, P, and K of maize plants, but the higher the dose of Zeolite applied up to 300 kg ha^{-1}, can reduce the absorption of N, P, and K nutrients from maize plants. Vice versa if the plants are given 0 kg ha^{-1} Zeolite then with an increase in the dose of NPK Phonska from 100 to 200 kg ha^{-1}, there will be an increase in nutrient uptake of N, P, and K, but it was increased more up to 300 kg ha^{-1} there will be reduced in transport nutrients both N, P, and K.

Tabel 3. Uptake N, P and K of maize plant at 54 dap affected by Zeolite and NPK Phonska

Zeolite	N-uptake			P-uptake			K-uptake		
dose	PONSKA Dose (kg ha^{-1})								
(kg ha^{-1})	100	200	300	100	200	300	100	200	300
	--g plant^{-1}---								
0	0.99Bc	1.94Aa	0.43Cb	0.51Bb	1.01Aa	0.26Ba	0.84Ab	0.37Bb	0.33Bb
100	2.74Aa	1.75Aa	0.57Bb	1.04Aa	0.71Aab	0.24Ba	2.12Aa	1.08Ba	0.34Cb
200	1.75Ab	1.09Ab	1.58ABa	0.83Aa	0.45Bb	0.56Ba	0.40Bb	0.17Bb	0.98Aa
CC (%)	18.14			17.08			18.90		

Numbers followed by the same uppercase letter in the same row and numbers followed by the same lowercase letter in the same column were not significantly different according to DNMRT 5% significance level

3.4 Maize Plant Growth And Leaf Area Index

The interaction effect of NPK Zeolite fertilizer and PONSKA was not significant, and there was no effect of a single factor on the growth of maize. If you look at the growth of the maize, it is quite normal for the height of plant. The effect of Zeolite and PONSKA did not significantly affect plant height. Likewise, the application of each Zeolite and NPK PONSKA did not significantly affect plant height (Table 4 and Figure 1). The correlation equation between the application of zeolite and PONSKA fertilizer was very low, which means there is no relationship.

Table 4. Effect of Ponska Zeolite and NPK application on plant height 8 DAP

Zeolite dose (kg ha^{-1})	Plant height (cm)			Leaf Area Index		
	PONSKA Dose (kg ha^{-1})					
	100	200	300	100	200	300
0	92,17	102,75	98,75	1.797	2.573	2.241
100	105,5	93,33	122,77	2.126	1.969	2.413
200	89,08	104,97	119,33	1.718	2.392	2.805
average	95.58B	100.33AB	113.62A	1.88 B	2.31 AB	2.49A
CC (%)	13.80			16,54		

Numbers followed by the same uppercase letter in the same row and numbers followed by the same lowercase letter in the same column were not significantly different according to DNMRT 5% significance level.

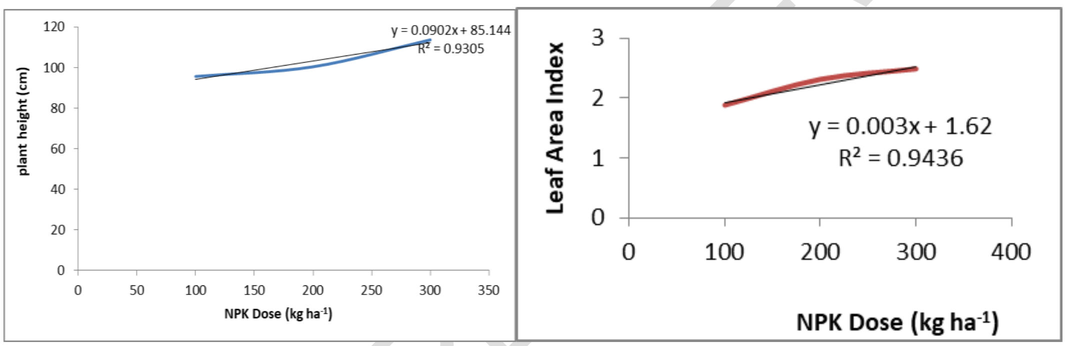

Figure 1. The relationship between each dose of PONSKA and Zeolite on plant height and LAI

Explanation : Zeolite (Z) (kg ha^{-1}) Z0 (0); Z1 (100); Z2 (200); NPK PONSKA (B) (kg ha^{-1}), B1 (100); B2 (200) and B3 (300)

3.5 The weight of 100 seeds and the yield of dry shelled maize

The highest weight of 100 maize kernels reached 23.93 g, and produced the highest dry shelled production of 5.44 t ha^{-1} from the 100 kg ha^{-1} Zeolite treatment and 200 kg ha^{-1} NPK Phonska (Table 5, Figure 2). The tendency of a high 100 seed weight resulted in the seeds formed on the cobs being pithy so that they could affect the weight of maize. The effect of the application of zeolite is not always good on the weight of 100 maize kernels, because the dose of zeolite which is increased again results in a decrease in the weight of 100 kernels, which also results in a decrease in the yield of dry maize.

Table 5. Weight of 100 seeds and yield of maize after giving NPK Phonska and Zeolit

Zeolite dose (kg ha^{-1})	100 seeds weight (g)			Yield of maize (tonnes ha^{-1})		
	PONSKA Dose (kg ha^{-1})					
	100	200	300	100	200	300

0	22.15 Aa	18.02 Ab	18.44 Aa	3.75 Ba	4.85 Ab	3.67 Bc
100	15.93 Bb	23.93 Aa	18.89 Ba	3.94 Ba	5.44 Aa	4.36 Bb
200	17.20 Bb	20.56 ABab	22.39 Aa	3.60 Ba	4.36 ABb	5.07 Aa
KK (%)	18,95			6,66		

Numbers followed by the same uppercase letter in the same row and numbers followed by the same lowercase letter in the same column were not significantly different according to DNMRT 5% significance level.

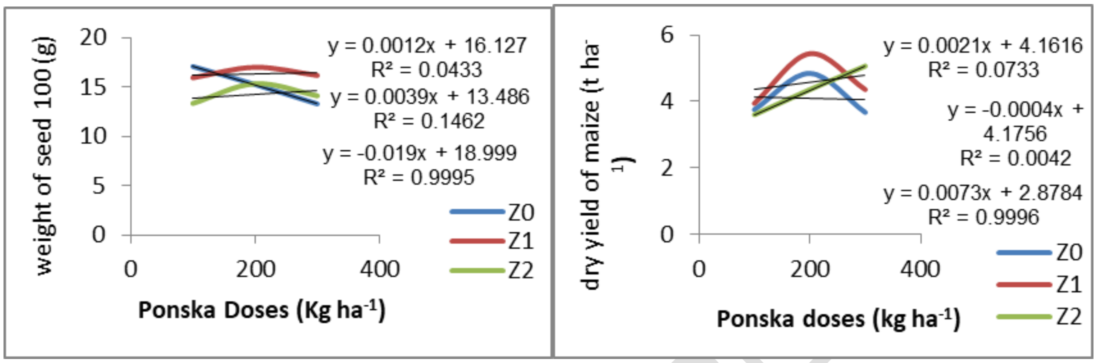

Figure 2. The relationship between the application of PONSKA and Zeolite on the weight of 100 maize's Kernels and on dry grain yield of maize

4. Discussion

The results of preliminary soil chemical analysis showed that the fertility of Inceptisols in Solok Selatan was in the low to moderate category, this was indicated by very low base saturation. The very low soil base saturation is due to the shallow exchangeable Ca content in the soil, whereas it has a high CEC (Table 1). The application of NPK PONSKA 100 kg ha^{-1} and Zeolite 100 kg ha^{-1} has an impact on a relatively high pH, but if the dose of NPK and Phonksa is increased too. There will be a decrease in soil pH, and it will return to normal if the soil is applied with 300 kg ha^{-1} NPK PONSKA accompanied by 200 kg ha^{-1} Zeolite (Table 2). The impact of a significant decrease in soil pH will usually disrupt the nutrient uptake of corn plants. However, the decrease in pH which is still > 5.7 allows for negligible interference with nutrient absorption. (11), have shown that nutrient P uptake of rice plants is also not affected by changes in pH. Likewise, previously (12) reported that higher doses of organic fertilizers were not linearly related to increased availability of nutrients N, P, and K.

The structure of the zeolite framework consists of tetrahedral units $(AlO4)^{-}_{5}$ and $(SiO4)^{-}_{4}$ which are bonded to each other via oxygen atoms to form zeolite pores. Silicon ions have a valence of 4, while aluminum has a valence of 3. This causes the zeolite structure to have an excess negative charge which is balanced by cations such as Fe and Al. Zeolites can convert unavailable P into available P by reducing the fixation power of P into Fe and Al cations, thereby increasing nutrient uptake in plants. According to (13) zeolite can increase P uptake by changing unavailable P conditions to available P. Zeolite is not classified as a fertilizer, so the application of zeolite must be followed by the application of fertilizer with the right dose.

(6) explained that Zeolite indicates a silica polymorph or crystalline aluminosilicate based on several maize er-sharing TO4 tetrahedrals (T = usually silicon and aluminum) form-ing a three-dimensional four-connected framework with regularly sized pores of molecular dimension. Zeolites are tectosilicates, hydrated crystalline aluminosilicates of alkaline and alkaline earth elements (cations). The siliceous zeolites are organophilic non-polar sorbents, while the aluminous ones are strong desiccants. Therefore, it has many roles

in the nutrient availability of maize. (13) told that it is necessary to apply zeolite based on local environmental conditions, especially CEC owned by soil. The application of zeolite will greatly help increase nutrient availability if the soil CEC was low. (14) has also explained that zeolite plays a large role in suppressing the loss of $N\text{-}NO_3^-$ from washing and can increase crop yields. Therefore it is important to apply zeolite with NPK so that nutrient leaching from NPK fertilizers can be minimized, so that nutrient availability increases. (15) also added that the application of zeolite can increase the efficiency of fertilization, furthermore (16) demonstrated the ability of zeolite to slow nutrient availability (slow release) so that it can provide nutrients throughout the life of the plant in accordance with the time or when the element is reqiured.

The zeolite influence on the soil's chemicals was not significant because the soil also had a high CEC as well. Subsequent effects were seen in the application of 200 kg ha^{-1} of zeolite, which generally reduced the uptake of N, P, and K nutrients in maize plants at 54 DAP. The impact of the high nutrient uptake then also has a good effect on the growth of plant height and the leaf area index of maize (Table 4, Figure 1). The pattern remained the same if given 200 kg ha^{-1} NPK PONSKA, there is a decrease in plant height and LAI. Plant nutrients that had been absorbed from fertilizers did not have a different effect if fertilizer was given a little or a lot. The same thing was also evidenced by (17); (18) demonstrated that plant height was largely determined by genetics or the variety of the plant, so if only 1 variety is planted, it will result in plants that grow normally will display plant heights that vary but were not significant.

Maize leaf area index (LAI) ranges from 1.718 – 2.805, maize LAI caused by Zeolite and PONSKA has no significant effect (Figure 3). The greater the LAI value indicates the more optimal the plant is in carrying out photosynthesis. According to (19) the LAI is determined not only by spacing but also by the variety of maize plants. The results of his research in determining LAI on maize varieties Bisi-2 and Pioneer-21, obtained maize LAI ranging from 0.17 to 0.40. Furthermore (20) demonstrated that the LAI of maize from 1.4-2.25 at 45-60 DAP. Likewise (21) have demonstrated that the LAI of the Sukmaraga variety ranges from 1.04-2.89, due to the application of manure 0-10 tonnes ha^{-1}. The increased leaf area will increase the amount of chlorophyll where photosynthesis is carried out to produce assimilate which are then sent to the female flower parts, namely the cobs for the formation of the cobs and seeds. (22) demonstrated that if a lot of assimilate is formed, the cob will be completely filled with seeds and the seeds are fully formed. The resulting maize kernels are a collection of carbohydrates, proteins, fats, and sugars derived from assimilating produced during photosynthesis.

Photosynthesis will take place well if maize leaves get optimal nitrogen, because the element N besides forming leaf chlorophyll also adds to plant cell tissue, whether leaf cells, stems, cobs, or seeds. As explained by (23) that nitrogen has the main function as a synthetic material for chlorophyll, protein, and amino acids. Therefore the element Nitrogen is needed in large enough quantities, especially when the growth enters the vegetative phase.

PONSKA NPK fertilization and zeolite application significantly increased the weight of 100 maize kernels and yield of maize (Table 5, Figure 2). However, there is an indication that the weight of 100 maize kernels is higher if the plants receive an application of 200 kg ha^{-1} NPK PONSKA and 100 kg ha^{-1} Zeolite, compared to other doses of NPK PONSKA and Zeolite. The weight of 100 maize kernels is also an indicator of obtaining the weight of dry husks in a certain unit area. If the weight of 100 seeds is high, of course, it will increase the dry-shelled weight in a certain unit area. The fully formed weight of maize is due to sufficient assimilation stored in the seeds resulting in a higher seed weight in every 100 seeds. Several other studies, (24) also proved that the weight range of shelled 100 maize kernels ranged from 20.05 – 24.56 g with this type of purple maize. A different matter was reported by (25) that who obtained a higher weight of 100 maize kernels ranging from 25.43-28.00 g, so he was able to produce high dry shells also reaching 7.79 tonnes ha^{-1}. The same thing

has also been proven by (26) those who obtained a high weight of 100 maize kernels and also in the same treatment produced the highest dry shell weight per hectare as well.
The highest maize yield reached 5.44 tonnes ha^{-1} from the application of 200 kg ha^{-1} NPK PONSKA followed by 100 kg ha^{-1} Zeolite. The graphical pattern of increasing dry-shelled maize yields presented in Figure 4 resembles the graphical pattern presented in Figure 5. This result is still low compared to the average maize yield in West Sumatra which reached 6.8 tonnes ha^{-1} (27) and the average in South Solok reached 6.11 tonnes ha^{-1} (28). However, when compared with the yield potential of this pioneer maize which is classified as superior, the yield is still relatively low, because the potential yield of this maize can reach 13.40 tonnes ha^{-1} (29). The results obtained from this study only reached 89.03% of the yield potential in Southern Solok. From these data, it can be explained that if there is only 100 kg ha^{-1} of zeolite available, then it is recommended to apply only 200 kg ha^{-1} of NPK PONSKA because if NPK PONSKA fertilizer is increased there will be a decrease in the dry maize weight.

5. CONCLUSION

Giving 100 kg ha^{-1} NPK PONSKA was able to provide optimal NPK nutrient uptake, plant height and LAI at 54 DAP. The combination of 100 kg ha^{-1} zeolite and 200 kg ha^{-1} NPK PONSKA provided optimal yields of dry shelled maize reaching 5.44 tonnes ha^{-1}.

CONSENT (WHERE EVER APPLICABLE)

All authors consent to their names appearing in this article

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