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Effect of cow manure and dolomite on nutrient uptake and growth of corn (*Zea mays* L.)

Suntoro Suntoro*, Heri Widijanto, Suryono, Jauhari Syamsiyah, D.W. Afinda, N. R. Dimasyuri, V. Triyas

Department of Soil Sciences, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Indonesia
**Corresponding author:* suntoro_uns@yahoo.co.id

Abstract

Suntoro, S., Widijanto, H., Suryono, Syamsiyah, J., Afinda, D. W., Dimasyuri, N. R., & Triyas, V. (2018). Effect of cow manure and dolomite on nutrient uptake and growth of corn (*Zea mays* L.). *Bulgarian Journal of Agricultural Science*, *24*(6), 1020–1026

The goal of this research is to discover the effect of cow manure and dolomite on the availability of nutrients N, Ca, and Mg, the growth of corn plants (*Zea mays* L.), and the uptake of nutrients by the plants. The field trial was carried out on *Oxic Dystrudept* soil, using a Randomized Complete Block Design (RCBD) with a two-way factorial arrangement. The first factor was manure with a dosage of 0, 5, 10, and 20 t Ha^{-1}. The second factor was dolomite with 4 levels, namely 0, 100, 200, and 300 kg Ha^{-1}. The results of the research showed that there was an interaction between cow manure and dolomite on plant growth, indicated by the plant biomass, the chlorophyll B content in the leaves, the uptake of nutrients N, P, Ca, and Mg, and the availability of P in the soil. The use of cow manure with a dosage of 20 t Ha^{-1} and dolomite at a level of 300 kg Ha^{-1} produced the highest plant biomass weight, namely 236.73 g $plant^{-1}$, or an increase of 438 percent compared with the control. The application of manure clearly influenced plant height, leaf area index, root weight, shoot weight, and N-total in the soil. The application of dolomite did not affect nutrient availability, nutrient uptake, or plant growth.

Keywords: corn; cow manure; dolomite; nutrient uptake

Introduction

Corn is the third most consumed food crop after wheat and rice (Karasu, 2012). Corn kernels consist of approximately 72% starch, 10% protein, 5% oil, 2% sugar, and 1% ash, the rest being made up of water. The biological value of corn protein is low due to the low concentration of the essential amino acids lysine and tryptophan, although a number of varieties of corn have been developed to increase the level of these amino acids (Blumenthal et al., 2008).

Corn productivity in Indonesia (4.1 t ha^{-1}) is lower than that in Thailand and Vietnam (Bisnis.com). The low productivity of corn is not only due to cultivation technology but also a number of other factors, such as soil acidity. The low pH of acidic soil causes a decrease in most of the nutrients, while aluminium and a number of micronutrients become more easily soluble and toxic for plants (Harter, 2007), and in addition it leads to a shortage of phosphorus (Brady, 1990).

The low level of phosphorus available in acidic soil is due to the fixation of the soluble phosphorus (P) by aluminium and iron so that it is no longer available for the plants. This condition can be minimized with organic amendments (Chng et al., 2015), such as manure. Several research studies have shown that manure has the ability to overcome the fixation of P by Al and Fe and to provide a source of P for plant growth. The application of poultry manure successfully increases the availability of P and also increases plant growth (Iqbal et al., 2016).

The process of pedogenesis of acidic soil involves a process of decalcification or cleansing of $CaCO_3$ and $MgCO_3$ (eluviation of $CaCO_3$) from the soil profile, meaning that the Ca and Mg content continue to decline throughout the process of soil weathering (Schroeder, 1984). Hence, the low availability of Ca and Mg in the soil also hinders plant growth (Hede et al., 2001). An attempt to overcome the low level of Ca and Mg nutrients can be made by adding dolomite. Calcium carbonate ($CaCO_3$) and dolomite ($CaCO_3MgCO_3$) are known as agricultural lime (Hede et al., 2001). The addition of a large quantity of dolomite to acidic soil is useful as a soil amendment to neutralize the aluminium and iron but in a small quantity its purpose is to increase the nutrients Ca and Mg (Suntoro et al., 2001c).

Another soil amendment that can be used in addition to lime is organic matter. The addition of organic matter to acidic soil will cause an increase in the content of the organic matter in the soil, the pH of the soil, the N-total in the soil, and the availability of macronutrients such as P, K, Ca, and Mg, as well as increasing the cation exchange capacity (CEC) and increasing plant production (Angelova et al., 2013). In the use of organic matter for fertilizer, the C/N ratio of the material needs to be noted. If the C/N ratio is still high, this means that the nutrients are not yet available for the plants, thus requiring the process of composting to be carried out first. The composting of organic matter such as organic waste can be used as a soil amendment material in the form of a nitrogen fertilizer and this helps to reduce the potential of environmental pollution (Ahmad et al., 2006).

Cow manure has a nutrient content which is complete and relatively available for the plants. This is due to the fact that the food material has undergone a perfect transformation in a short period of time. The animal uses only half of the organic matter it eats and the rest is emitted as waste. Some of the solids contained in manure are made up of organic compounds similar to the food material the animal has eaten, including cellulose, starch and sugar, hemicellulose and lignin that can be found in the ligno-protein of humus (Suntoro, 2003). Chesson (1997) explains that in the rumen, the transformation process of organic matter can take place efficiently because the microbes are able to work optimally, since the rumen is the ideal habitat for the breakdown process to take place. The rate of transformation in the rumen is faster than in the soil; the time needed to break down the cell walls in the rumen is only a day while in the soil it takes weeks.

In crop cultivation on dry land, farmers consider cow manure to be a determining factor for crop production (Suntoro et al., 2001a). Composting is required for poultry waste, and the nutrient content in composted poultry waste is higher than fresh waste, and this influences the biomass of corn plants (Faridullah et al., 2014). Ipinmoroti et al. (2008), in their research on tea plants, show that cow manure contains a number of nutrients, N, P, K, Ca, and Mg, that affects the growth and yield of dried tea leaves. Cow manure has undergone a perfect breakdown, thus making its nutrients more readily available. Cow manure contains the following nutrients: 26.2 kg t^{-1} N; 4.5 kg t^{-1} P; 13.0 kg t^{-1} K; 5.3-16.28 kg t^{-1} Ca; 3.5-12.8 kg t^{-1} Mg, 2.2-13.6 kg t^{-1} S. The use of cow manure has an effect on both the physical and chemical properties of the soil (Suroyo et al., 2013). The use of manure on corn plants shows that cow manure affects the production of the stem, the kernels, and the quality of the corn plants (Farhad, et al., 2009).

The use of organic fertilizer in combination with lime on acidic soil has a highly beneficial effect in increasing the availability of nutrients for plant growth and in conserving the fertility of the soil (Jokubauskaite et al., 2015). The residual effect of the manure and compost is important for the next planting season. When manure is applied regularly, the organic matter in the soil will increase over time. The continual use of fertilizer or compost may cause an increase in the levels of residue of N, P, and other nutrients. In general, the amount of N released from the organic N in the second and third years after the initial application is respectively 50% and 25% of the mineralization during the first planting season (Koutev and Nenov, 2016). The goal of this research is to discover the effect of cow manure and dolomite on the availability of the nutrients N, Ca and Mg on the uptake of nutrients by plant and on plant growth.

Materials and Methods

This field research was carried out in the Tirtomoyo sub district of the Wonogiri district in the province of Central Java. The research was a factorial trial with two factors arranged using a Randomized Complete Block Design (RCBD). The first factor was 4 levels of cow manure: M0 = no cow manure as the control, M1 = 5 t ha^{-1}, M2 = 10 t ha^{-1}, and M3 = 20 t ha^{-1} cow manure. The second factor was 4 levels of dolomite: D0 = without dolomite as the control, D1 = 100 kg ha^{-1}, D2 = 200 kg ha^{-1}, and D3 = 300 kg ha^{-1} dolomit. Thus, there were 16 different treatments, each of which was repeated 3 times. For the observation of plant growth, samples of soil and plants were collected for analysis 55 days after planting, which was the time of maximum vegetative growth.

The factors observed included: (1) nutrient availability in the soil, including N-total in the soil using a method of titration, P-available using the Bray I method, Ca and Mg-exchanged using the buffer solution method NH_4-OAc pH 7; (2) uptake of nutrients N, Ca and Mg with extraction through wet oxidation with HNO_3 and $HClO_4$, and (3) plant growth: plant height, plant biomass of plant roots and shoots, leaf area index, and chlorophyll content.

The type of soil in the research area was *Oxic Dystrudepts* with a texture of silty clay, a pH (H_2O) of 5.4 (acidic), a low cation exchange capacity (11.20 cmol (+) kg^-), a low level of fertility with nutrient content N-total 0.19% (low), P-available 1.87 ppm (low), K-exchanged 0.347 cmol (+) kg^{-1} (low), Ca-exchanged 6.5 cmol (+) kg^{-1} (average), and Mg-exchanged 0.6 cmol (+) kg^{-1} (average). The cow manure used contained 1.62% N, 0.27% P, 0.29% K, 0.53% Ca, and 0.96 % Mg. The dolomite (Ca Mg $(CO_3)_2$) had a content of 21% Ca and 10.8% Mg.

Results and Discussion

Nutrient availability

The results of the experiment showed that the addition of cow manure had a significant effect on the N-total content in the soil ($p < 0.05$) (Table 1). Cow manure is a source of element N and as such, its application to the soil can increase the N-total in the soil. When cow manure is added to the soil, it influences the process of mineralization, producing nitrate (NO_3) and ammonium (NH_4) for plant growth (Sun-

Table 1. Effect of cow manure and dolomite on plant growth, N-total in the soil, and P uptake

Treatment	Plant height (cm)	Dry root weight (g)	Fresh shoot weight (g)	LEI (cm^2)	N-total in soil (%)	P uptake (g)
Cow manure (M)	$p < 0.01$ **	$p < 0.01$ **	$p < 0.01$ **	$p < 0.01$ **	$p < 0.05$ *	$p > 0.05$ ns
M0	124.15 b	7.89 c	162.92 c	655.74 b	0.48 b	1.13 c
M1	165.92 a	15.92 bc	322.83 b	880.58 a	0.52 b	2.33 b
M2	179.10 a	26.00 b	388.50 ab	970.15 a	0.55 ab	2.38 ab
M3	178.82 a	41.00 a	435.75 a	1021.15 a	0.61 a	3.19 a
Dolomit (D)	$p > 0.05$ ns	$p > 0.05$ ns	$p > 0.05$ ns	$p > 0.05$ ns	$p < 0.01$ **	$p < 0.05$ *
D0	154.46	22.15	290.25	901.49	0.54 b	1.94
D1	167.78	22.62	354.25	902.75	0.62 b	2.17
D2	161.24	19.89	309.25	874.10	0.52 ab	2.27
D3	164.52	26.15	356.25	849.26	0.48 a	2.65
Interaction efect (Cow manure x Dolomit)	$p > 0.05$ ns	$p > 0.05$ ns	$p > 0.05$ ns	$p > 0.05$ ns	$p > 0.05$ ns	$p > 0.05$ ns

Table 2. Effect of interaction of cow manure and dolomite on P availability, nutrient uptake, chlorophyll B and total plant biomass

Treatment	N uptake (%)	P available (ppm)	Ca uptake (g)	Mg uptake (g)	Chlorophyll B	Plant biomass (g)
D0M0	0.08 g	2.459 bc	63.86 fg	9.16 fgh	0.65 f	43.87 efg
D0M1	0.20 defg	2.113 c	85.28 defg	12.77 efgh	0.86 abc	74.40 defg
D0M2	0.22 cdefg	1.900 c	99.41 defg	20.94 defgh	0.86 abc	72.27 defg
D0M3	0.43 b	2.506 bc	180.43 abc	40.34 bc	0.85 abc	135.60 abc
D1M0	0.08 g	2.002 c	41.04 g	7.23 h	0.66 ef	40.80 g
D1M1	0.28 bcdefg	2.183 c	131.67 cde	29.46 bcde	0.80 bcd	95.73 cde
D1M2	0.43 b	3.056 bc	208.46 ab	45.04 b	0.74 d	178.53 ab
D1M3	0.31 bcde	6.836 a	142.01 bcde	32.85 bcd	0.79 cd	116.93 cde
D2M0	0.14 fg	2.173 c	41.65 g	8.93 gh	0.57 g	55.93 fg
D2M1	0.35 bcd	1.961 c	115.05 cdef	25.67 cdefg	0.88 a	104.93 defg
D2M2	0.39 bc	5.968 a	156.92 bcd	34.94 bcd	0.80 bcd	85.73 cde
D2M3	0.40 bc	3.958 bc	134.46 cde	30.55 bcde	0.86 abc	114.73 bcd
D3M0	0.17 efg	2.683 bc	79.48 efg	19.18 defgh	0.74 de	54.73 defg
D3M1	0.26 bcdefg	2.978 bc	107.70 defg	27.29 bcdef	0.80 bcd	97.93 defg
D3M2	0.26 cdef	2.824 bc	131.48 cde	30.56 bcde	0.83 abc	101.40 cdef
D3M3	0.62 a	6.243 a	235.47 a	66.81 a	0.87 ab	236.73 a
Interaction efect KxD (Cow manure x Dolomit)	$p < 0.05$ *	$p < 0.01$**	$p < 0.05$ *	$p < 0.05$ *	$p < 0.01$ **	$p < 0.05$ *
Cow manure (K)	$p < 0.05$ **	$p < 0.01$**	$p < 0.01$ **	$p < 0.01$ **	$p < 0.01$ **	$p < 0.05$ *
Dolomit (D)	$p > 0.05$ ns	$p < 0.01$**	$p > 0.05$ ns	$p < 0.05$ *	$p < 0.01$ **	$p > 0.05$ ns

toro, 2003). The application of manure at a level of 20 t/ha increased the N-total in the soil by 27% compared with the control. This is in line with Harieni and Minardi (2013), who wrote that the addition of manure has the effect of increasing the N-total in the soil. Cow manure is considered mature and contains nutrients available for plants, since it has already undergone a perfect process of transformation in the cow's rumen (Chesson, 1997). Two processes, which are responsible for the mineralization of organic matter in the soil, are the process of ammonification and the process of nitrification. The ammonification process works well on soil that is well drained and well aerated and on soil with high alkaline cation content. These conditions are present in corn cultivation which requires good aeration. Corn plants can use this type of ammonium for growth while a part of it undergoes a process of nitrification. Since nitrification is an oxidation process, it requires good aeration (Brady, 1990). Thus, the addition of cow manure is proven to increase the amount of N-total in the soil (Table 1). This is in line with the research of Suroyo et al. (2013), which shows that the integration of manure on corn plants has a significant effect on increasing the N-total in the soil.

The research results showed that there was a highly significant interaction between the addition of cow manure and the application of dolomite ($p < 0.01$) on P availability (Table 2). The response to the addition of cow manure was to increase the P availability in the soil, bearing in mind the status of P availability in the location of the research was low, which meant that it responded well to the addition of the P nutrient. Throughout the process of mineralization, cow manure releases P into the soil. The process of decomposition and mineralization of organic matter not only leads to the release of inorganic phosphor (PO_4^{3-}) but also releases P-organic compounds such as phytin and nucleic acid, and it is believed that the plant can make use of these P-organic compounds (Tisdale and Nelson, 1975). The mineralization process of organic matter takes place if the P content of the organic matter is high, which is often stated using the C/P ratio (Stevenson, 1982). Plants do not have the ability to absorb and utilize the soil's P-organic matter. Through the process of mineralization, the inorganic phosphates released make P available for uptake by the plant. The plant absorbs P as a phosphate anion (HPO_4^{-} or $H_2PO_4^{-}$) from the soil solution.

The cow manure used in this research had quite a high P content – 0.27 % P. This corresponds to the results of a research study which shows that the addition of cow manure increases P availability in the soil and this continues to increase further when combined with dolomite (Suntoro et al., 2001b). The highest level of P availability was obtained with an application of cow manure at a level of 20 t ha^{-1}and dolomite at a level of 50 kg ha^{-1}, which increased P availability by 177% compared with the control. The application of cow manure with a dosage of 20 t/ha always showed a high P availability (D1M3 and D3M3 were not significantly different).

The results of the research showed that the addition of cow manure and dolomite did not have any effect on the Ca and Mg exchanged in the soil ($p > 0.05$), and this was also the case with the interaction of the two. This was due to the status of the Ca and Mg exchanged nutrients in the soil which was at an average level, and as such, an increase up to the level of 300 kg/ha did not result in any significant increase.

Nutrient uptake

The research results showed a significant interaction between cow manure and dolomite on the N uptake of plants ($p < 0.05$). The highest N uptake of the plants was obtained with the treatment combination of cow manure at a level of 20 t ha^{-1} and dolomite at a level of 300 kg ha^{-1}, which resulted in an uptake of 0.62 g plant^{-1}, or an increase of 6.67 times as much as in the control (Table 2). This increase was caused by an increase in the N-total in the soil after the application of manure, and the effect caused by the addition of manure increased further with the addition of dolomite. The application of manure without the addition of dolomite showed an increase 4.73 times that of the control, while the addition of dolomite without manure produced an increase of only 1.12 times that of the control.

The results of the research showed that the application of manure had a significant effect on the P uptake of the plants ($P < 0.01$). The treatment using a dosage of 20 t ha^{-1} of manure showed the highest result, resulting in an uptake of 3.18 g plant^{-1} or an increase in 181 percent compared with the control (Table 2), while the lowest result was obtained in the control treatment with a value of 1.13 g plant^{-1}.

The results of the analysis of different variants showed that there was a significant interaction between the application of manure and dolomite on the Ca uptake of the plants ($p < 0.05$). The highest Ca uptake occurred with the treatment of cow manure at a level of 20 t ha^{-1} and dolomite at a level of 300 kg ha^{-1}, which resulted in an uptake of 235.47 g Ca plant^{-1}, or an increase of 86% compared with the control. The result was the same for Mg uptake. There was a significant interaction between the application of manure and dolomite on the Mg uptake of the plants ($p < 0.01$). The application of cow manure at a level of 20 t ha^{-1} and dolomite at a level of 300 kg ha^{-1} resulted in the highest Mg uptake, namely 66.81 g Mg plant^{-1}, or an increase of 6 times as much as the control.

The increase in Ca and Mg uptake was due to the supply of Mg in the cow manure through the process of mineralization, as well as the addition of dolomite. This is in line with the research by Suntoro et al. (2001b) which shows that the application of cow manure increases Ca and Mg uptake of peanut plants and that the effect is greater when combined with the addition of dolomite.

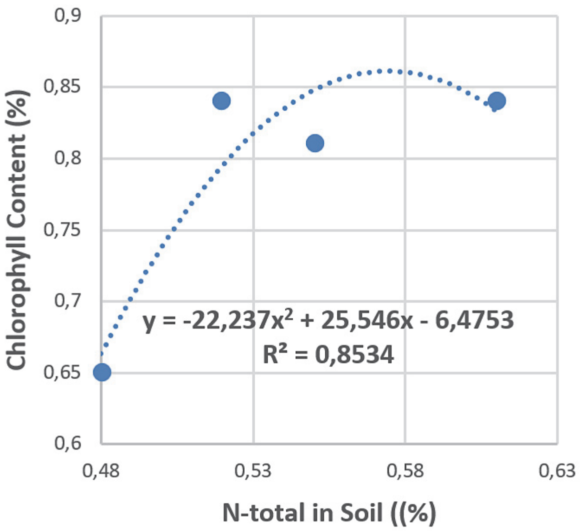
The application of cow manure at a level of 20 t ha^{-1} without dolomite resulted in a Ca uptake of 180.43 g $plant^{-1}$, while the addition of dolomite without manure showed a Ca uptake of only 79.48 g $plant^{-1}$. The result was the same for Mg uptake. The application of manure without dolomite produced a Mg uptake of 40.34 g $plant^{-1}$, while the application of dolomite without manure produced an increase of only 19.18 g $plant^{-1}$. These results indicate that manure provides a greater supply of Ca and Mg than dolomite.

Plant growth

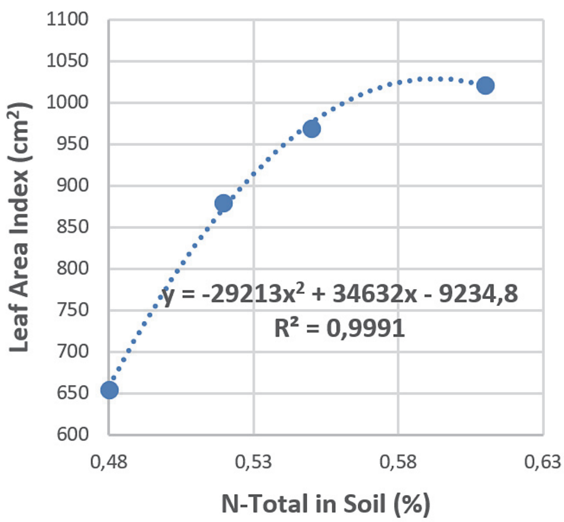
The increase in the availability of nutrients N and P in the soil affected the nutrient uptake of the plants, which in turn affected plant growth. The research results showed that the application of manure had a highly significant effect ($p < 0.01$) on plant height, leaf area index, plant root biomass, and plant shoot biomass (Table 1). The application of dolomite had no effect on the parameters of plant growth. However, there was a significant interaction between cow manure and dolomite on the chlorophyll B content of the leaves ($p < 0.01$) and the total biomass of the plants ($p < 0.05$) (Table 2). The highest plant biomass was obtained with the treatment of cow manure at a level of 20 t $ha^{-1}$and a dolomite level of 300 kg ha^{-1}, which resulted in a biomass of 236.73 g $plant^{-1}$, or an increase in 438 percent compared with the control.

The availability of the nutrient N in the soil encourages plant growth because nitrogen regulates the use of other elements for growth. Nitrogen is an important element for plant nutrition and a determining factor in production of corn. The primary role of N in plants is to form amino acids, protein, nucleic acid, and phytochromes. Thus, N is the motor for plant growth and makes up between 1 to 4% of dry matter of plants (Bashir et al., 2012). Therefore, the accumulation of N has a significant effect on the kernels and protein content of corn plants (Karasu, 2012). The sufficient availability of N during the planting season is extremely important for optimal corn growth (Umeri et al., 2016). Therefore, addition of the nutrient N will increase growth and yield of plants (Blumenthal et al., 2008) (Table 1). This also corresponds to the research of Harieni and Minardi (2013), which shows that manure has an impact on plant biomass. It even has an impact on the residue which in turn affects the next planting season.

The research results showed that there was a highly significant interaction between cow manure and dolomite on the chlorophyll content of the leaves (Table 2). The application of cow manure had an effect on the chlorophyll content of the leaves and the effect became more significant if combined with dolomite. The highest chlorophyll content was obtained with the application of manure at a level of 20 t ha^{-1} combined with dolomite at a level of 300 kg ha^{-1}, which pro-



a. Relationship between N-total in soil and chlorophyll content (%)



b. Relationship between N-total in soil and leaf area index (cm^2)

Fig.1. Relationship between N-total in soil with chlorophyll content (%) and leaf area index (cm^2)

duced an increase of 0.88% in chlorophyll content. This is closely related to the effect of the nutrient N that is released by the cow manure together with the nutrient Mg released by the dolomite. These two nutrients have a highly significant effect on chlorophyll formation. As a structural unit of chlorophyll, N forms porphyrins that are used in the metabolism of chlorophyll. The relationship between the N-total content in the soil and the chlorophyll content of leaves is shown in Fig. 1a. The nutrient Mg, meanwhile, plays a role in the formation of the essence of chlorophyll. This is proven by the interaction between the manure and dolomite on the effect of Mg uptake and on the chlorophyll content of corn leaves (Marschner, 1986).

In addition to releasing the nutrient N, cow manure also affects the availability of P in the soil, thus influencing plant growth. The nutrient P plays an important role in various processes of plant growth, including biochemical reactions such as the metabolism of carbohydrates, fats, and proteins (Umeri et al., 2016). In addition, the nutrient P also forms metabolites, complex compounds, and organic components, and plays a part in the formation of phosphoproteins, phospholipids, phosphate sugars, enzymes, and high energy phosphate compounds (ATP) which are very important in the growth process (Marschner, 1986), as well as acting as an essential nutrient in the formation of new cells. Therefore, the nutrients N and P that are produced as a result of the mineralization process of cow manure have a determining role in plant growth, which is shown in this research by plant height, root and shoot biomass, and leaf area index. These results are also in line with the research of Iqbal et al. (2016), which shows that the application of manure increases plant growth, leaf area index, and plant biomass. The nutrient N produced by mineralization of the cow manure plays an important role in plant growth, including the formation of leaves. The relationship between the availability of N in the soil and leaf area index is presented in Fig. 1b.

Conclusions

The interaction between the application of cow manure and dolomite had an effect on plant growth, as shown by the plant biomass; chlorophyll B content in leaves; uptake of nutrients P, Ca and Mg by the plant; and P availability in the soil. The highest plant biomass was obtained using a combination of treatment of cow manure at a level of 20 t ha^{-1} and dolomite at a level of 300 kg ha^{-1}, which produced a biomass of 236.73 g $plant^{-1}$, or an increase of 438 percent compared with the control. The application of manure had an effect on plant growth, as shown by plant height, leaf area index, root weight, shoot weight, and the influence on N-total in the soil. The application of dolomite did not have an effect on nutrient availability, nutrient uptake, or plant growth.

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