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Growth and Yield of Corn Plants Against Vermicompost Dosage in Degraded Ultisols

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ABSTRACT

Ultisols has prominent weaknesses and problems such as high acidity levels, low water absorption capacity, and low nutrient content such as N, P, K, Ca, and Mg, so it has the potential to inhibit plant growth. One way to overcome Ultisols soil problems is to use vermicompost fertilizer. Corn is one of the plants that is suitable for cultivation using vermicompost fertilizer. The research aims to obtain the best dose of vermicompost for corn growth and yield in degraded Ultisol soil. The research was conducted in Sri Kuncoro Village, Pondok Kelapa District, Central Bengkulu Regency, Bengkulu Province. The design used a single-factor Complete Randomized Block Design (RCBD) consisting of 5 treatment levels and five replications to obtain 25 experimental plots of 0, 7.5, 15, 22.5, and 30 tons ha-1. Data were analyzed using Analysis of Variance (ANOVA) at a 5% level and continued with the Least Significant Difference (LSD) test at a 5% level. The research results showed that the dose of vermicompost significantly affected the variables of plant height, number of leaves, number of leaves, and plant dry weight. The best vermicompost treatment dose was 22.5 tons ha-1 with plant height 254.85 cm, number of leaves 13.26, stem diameter 24.90 mm, leaf area 811.49 cm^2, cob length with husk 24, 93 cm, cob length without husk 17.26 cm, cob weight with husk 218.19 g, cob weight without husk 194.26 g, dry seed weight of plant samples 153.33 g and Dry seed weight per ha 9.1 tons.

Keywords : *corn, Ultisol, vermicompost*

INTRODUCTION

Corn (*Zea mays* L.) is a plant that has quite high economic value. Corn is a source of carbohydrates as food, feed for livestock, industrial raw materials, and bioethanol raw materials. With the increasing population, the need for food is increasing. Several things must be considered in increasing corn production, such as superior seeds, intensification, and extensification. Intensification is the activity of maximally managing existing land, while extensification is the expansion of planting areas.

The largest corn producer in the world currently is the United States, based on average data from 2014 to 2018 of 381.78 million tons (34.52%), while Indonesia only has around 24.27 million tons (2.19%) (Kementan, 2021). The corn planting area that must be achieved in 2022 is around 4,265,068 million with a harvest area of 4,117,497 ha and production of 23,103,448 tons. Optimizing corn production can be done by expanding land and fertilizing. Expanding corn cultivation land can be done by utilizing marginal land such as ultisol.

Ultisol is a type of soil that is widely distributed in Indonesia and has great potential to be developed into agricultural land. Ultisol soil is a type of soil that is classified as marginal soil (soil with limiting factors). The area of ultisol in Indonesia reaches 45,794,000 ha or 25% of Indonesia's land area, spread across several islands in Indonesia such as Kalimantan, Sumatra, Sulawesi, Papua, Java, and Nusa Tenggara. The prominent weaknesses of ultisol are low pH, low CEC, low base saturation, low nutrient content such as N, P, K, Ca, and Mg, and high levels of exchangeable Al, resulting in the unavailability of sufficient nutrients for plant growth (Stepanus *et al*., 2014). Meanwhile, in the Bengkulu area, the ultisols land coverage is 0.71 million ha, which is second only to Inceptisols, which cover more than 0.99 million ha (Prawito *et al*., 2022).

In this study, ultisol soil with a degraded ultisols classification was used. Ultisols is degraded to a worse quality in terms of macro and micro nutrient content compared to ultisol in general. Degraded ultisol is land that has generally experienced a decrease or damage to its quality and benefits, whether caused by nature or humans (Pranowo *et al*., 2015). A further consequence of this land degradation process is the emergence of unproductive areas called critical land. Currently, these lands spread across Indonesia have reached 48.3 million hectares. The way to overcome the problem of degraded ultisol is the same as ultisol in general, namely by adding organic materials (Wahyunto & Dariah, 2014).

Problems with the chemical, physical, and biological properties of ultisol soil can cause problems in increasing plant growth (Kasno & Rostaman, 2013). Increasing the productivity of ultisol soil requires physical and chemical improvements of the soil so that it can be used for agricultural cultivation. One of them is corn cultivation, the determining factor for the success of corn cultivation is sufficient nutrients for optimal growth and development (Yozie *et al*., 2016). To increase nutrient availability for corn plants, adding organic fertilizer is very effective, one of which is vermicompost fertilizer.

Vermicompost is the result of earthworm feces, including organic fertilizer that is environmentally friendly and contains high nutrients (Suparno *et al*., 2013). The quality of vermicompost fertilizer is better than compost, especially the levels of N, P, and K. Vermicompost contains N 1.41%, P 0.77%, and K 2.14%, while compost fertilizer has an N content of 0.67%, P 0.75%, and K 1.80% (Riwandi *et al*., 2015). Vermicompost can improve soil quality, thereby increasing corn production which is characterized by much higher pH and corn crop yields (Nurjanah *et al*., 2020). Good vermicompost from animal waste meets the quality standard requirements according to SNI 19-7030-2004 with a pH of 6.80-7.49, water content of 50%, very fine texture, earthy smell, black color, and the highest quality vermicompost is close to SNI 19 -7030-2004 comes from cow dung (Stepanus *et al*., 2014). Vermicompost produces soil modifications that have a high particulate surface area which maintains space for microbial activity, namely bacteria, fungi, and actinomycetes, regulates nutrients in the soil, and changes variable properties and results related to growth (Aslam & Ahmad, 2020).

Vermicompost can increase the nutrient content in ultisol soil for the growth of corn plants because it contains humic substances, which are humus materials that play a role in inorganic reactions in the soil and are also involved in complex reactions that can both directly and indirectly affect plant growth (Fatahillah, 2017). The research results of Riwandi *et al*. (2020) show that the dry seed weight of corn is 9.9 tons ha^{-1} at a vermicompost dose of 15 tons ha^{-1}. Vermicompost contains humic acid, which increases lateral root enlargement in corn. Vermicompost also increases nutrient absorption by plants by increasing the membrane permeability of root cells, increasing root hair proliferation, and stimulating root growth (Dominguez & Edwards, 2010).

MATERIALS AND METHODS

This research was conducted in July – December 2022 in Sri Kuncoro Village, Pondok Kelapa District, Central Bengkulu Regency, Bengkulu Province. The experimental design carried out was a randomized complete block design (RCBD) with 5 vermicompost dosage levels i.e. V_0 = 0; V_1 = 7.5; V_2 = 15; V_3 = 22.5; and V_4 = 30 tons ha^{-1}, each repeated 5 times. The plot measures 3 m x 2 m and the planting distance is 75 cm x 20 cm. The number of plants per plot is 40 plants per plot. The distance between plots is 1 m and the distance between plots and the edge of the land is 2 m, so the total land area is 414 m^2.

Observed variables include; plant height, number of leaves, number of leaves, leaf area, plant fresh weight, plant dry weight, cob length with husk, cob length without husk, cob weight with husk, cob weight without husk, dry seed weight plant sample, and dry seed weight per hectare. The research data were analyzed statistically using ANOVA with an α level of 5% and a comparison of averages was carried out using the Least Significant Difference (LSD) test.

RESULTS AND DISCUSSION

This research was carried out from August to December 2022, located in Sri Kuncoro Village, Pondok Kelapa District, Central Bengkulu Regency, Bengkulu Province. During the research, it often rained for days because of the planting season in the August to December period. Data from the Bengkulu Meteorology, Climatology, and Geophysics Agency shows that rainfall in August, September, October, November, and December was 180 mm, 210 mm, 230 mm, 250 mm, and 202 mm, respectively. The average air temperatures are 28.5 ^{0}C, 27.2 ^{0}C, 27.9 ^{0}C, 27 ^{0}C and 28 ^{0}C, respectively. Air humidity is respectively 90%, 85.1%, 92%, 88.8% and 89%. Corn plants require rainfall of around 85 mm - 200 mm $month^{-1}$ evenly (Killa *et al*., 2019). The optimum temperature required for corn plants is 26 ^{0}C – 31 ^{0}C (Wirosoedarmo *et al*., 2011). In this study, the conditions of rainfall, temperature, and air humidity were quite suitable for corn plants. Corn planting does not depend on the season, but requires sufficient water availability to make corn grow better (Riwandi *et al*., 2014).

The previous research land was land that had been excavated for making bricks which had been abandoned for several years and included degraded ultisols. Degraded ultisol is ultisol that has experienced a decline in the complex physical, chemical, and biological qualities of the soil. Efforts to improve degraded ultisols include using the addition of organic materials or microorganisms. The analysis results show that this research land has an organic C content of 2.86% (low), P 4.46 ppm (low), exchangeable Al 1.01 Cmol kg^{-1} (medium), pH 5 (sour), and exchangeable K 0.29 Cmol kg^{-1} (low). Based on the soil pH value (5.6 – 7.5), it is considered an ideal soil condition for corn plants (Vien *et al*., 2023). To increase the pH of the soil, liming is carried out by applying dolomite before planting.

During the research, the corn plants experienced good growth and no plants fell over. Corn plants in the vegetative phase of 4 WAP to 7 WAP experience attacks by armyworm pests (*Spodoptera frugiperda*). This pest attacks the shoots, characterized by symptoms of holes in the top of the leaves, traces of friction from caterpillars, and coarse powder such as sawdust found on the upper surface of the leaves. Control is carried out by spraying insecticide containing the active ingredient emamectin benzoate 30 g L^{-1} with a concentration of 30 mL 15 L^{-1} of water routinely twice a week. Armyworm attacks decreased after spraying from 40% to 15%. A decrease in armyworm attacks was observed after 1 day of spraying, marked by the death of the armyworms. The fall armyworm attack ends with the appearance of new leaves without any damage such as holes and broken leaves. The generative phase of corn plants begins at 52 DAP marked by the appearance of male flowers.

The growth pattern of corn plants can be seen in the vegetative phase of the plant, which is represented by plant height, number of leaves, and stem diameter. Plant height growth was observed from 2 WAP - 7 WAP. The highest plant growth was in treatment V_4, and the lowest was in treatment V_1 (Figure 1). Plant height growth increases rapidly at the V_4 dose, namely week 6 to week 7. Rapid growth after entering the final vegetative phase means the plant height reaches its maximum height before the male flowers appear. Nutrient and water requirements tend to increase to support plant growth rates (Subekti *et al*., 2007) as the dose of vermicompost increases, plant height growth from week 6 to week 7 in V_4 appears to be increasing. Vermicompost increases available N uptake and vermicompost dosage (Palandi, 2010).

Based on the growth of number of leaves observed from 2 WAP to 7 WAP (Figure 2), a rapid increase in number of leaves occurred at 6 WAP to 7 WAP because the plant entered the final vegetative period.

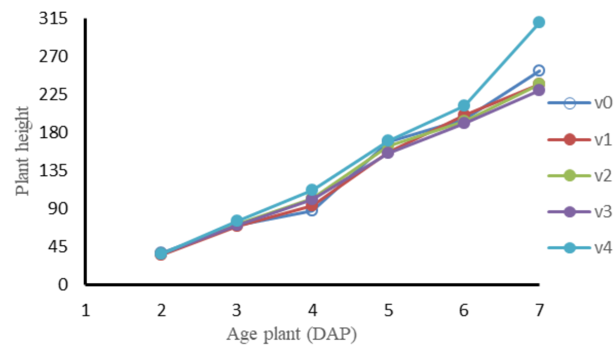

Figure 1. Plant height growth aged 2 WAP to 7 WAP

The highest number of leaf growth was in treatment V_3 and the lowest number of leaf growth was in treatment V_2. The results of research by Sintia (2011) show that in the 6th to 7th week of plant life, the number of leaves increases rapidly because it is directly proportional to plant height. The growth of the number of leaves is very good for the continuity of plant photosynthesis. According to Hapsoh (2023), the greater the number of leaves, the more light is absorbed for the photosynthesis process. The growth in several leaves from the research results is thought to be influenced by the uptake of N elements from vermicompost. The N element contained in vermicompost plays a role in photosynthesis and is needed for the synthesis of amino acids which function in the growth of several leaves (Gardner *et al*., 1991).

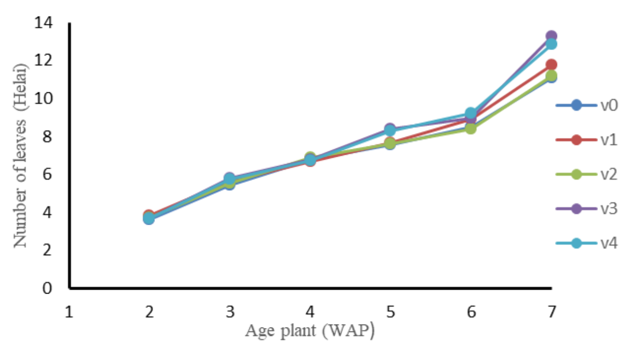

Figure 2. Growth in number of leaves aged 2 WAP to 7 WAP

Stem diameter is an important factor for plants because it is useful for supporting the plant so that it does not fall over. Stem diameter growth was measured at 2 WAP to 7 WAP (Figure 3). Stem diameter growth experienced a rapid increase from 2 WAP to 4 WAP. The V4 treatment produced the largest stem diameter growth and the lowest was produced by the V_1 treatment. Stem diameter growth after 4 WAP to 7 WAP does not occur quickly. The growth of corn stem diameter increasingly slows towards the final vegetative phase because plant nutrition is more focused on strengthening the stem (Elizabeth *et al.*, 2016) .

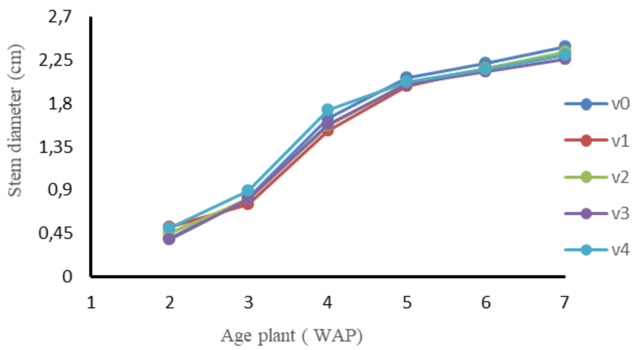

Figure 3. Stem diameter growth from 2 WAP to 7 WA

Providing different doses of vermicompost in degraded ultisol had a significant effect on the variables of plant height, number of leaves, stem diameter, and plant dry weight. Meanwhile, the variables that did not have a significant effect were leaf area, plant fresh weight, cob length with husk, cob length without husk, cob weight with husk, cob weight without husk, dry seed weight sample, and dry seed weight per hectare (Table 1).

Table 1. Summary of results of variance analysis of observed variables

Variable	F value	CV (%)
Plant height	3.90*	8.12
Number of leaves	5.17*	8.05
Stem diameter	14.82*	3.43
Leaf area	2.84 ns	4.8
Plant fresh weight	1.61 ns	10.71
Plant dry weight	3.29*	15.34
Cob length with husk	2.62 ns	5.18
Cob length without husk	1.68 ns	12.48
Cob weight with husk	1.22 ns	24.73
Cob weight without husk	1.17 ns	25.86
Dry seed weight of plant samples	1.88 ns	21.93
Dry seed weight per ha	1.29 ns	31.79

Note : * = significant ; ns = not significant; CV = Coefficient of Variation

Treatment V_3 produced the tallest plants and was significantly different from treatments V_2 and V_0, but not significantly different from treatments V_4 and V_1. Meanwhile, treatment V_4 was significantly different from V_0, but not significantly different from treatments V_3, V_1, and V_2. The V_0 treatment produced the lowest plant height compared to other treatments (Table 2).

Table 2. Average growth of corn plants when dosed with vermicompost

Treatment	PH (cm)	NL (helai)	SD (mm)	LA (cm^2)
V_0	213.60 c	11.09 c	21.30 c	736.86
V_1	237.5 abc	11.73 bc	22.80 b	780.96
V_2	228.29 bc	11.16 c	22.70 b	796.96
V_3	254.85 a	13.26 a	24.90 a	811.49
V_4	251.67 ab	12.83 ab	24.30 a	791.83

Note : Numbers in the same column followed by the same letter are not significantly based on LSD at level 5%. PH = Plant height, NL = Number of leaves, SD = Stem diameter, dan LA = Leaf area.

The tallest plant was in the V_3 treatment at 254.85 cm and the lowest was in the V_0 treatment at 213.6 cm. Plant height in V_3 has exceeded the potential height of the Bisi 18 seed variety, namely 230 cm. It is suspected that the content available in 22.5 tonnes ha^{-1} of vermicompost fertilizer is very good in meeting the needs of the plant growth period. Vermicompost also contains auxin which is useful for stimulating plant height growth. According to Palandi (2010) providing vermicompost can increase N uptake which is useful for plant height growth. The research results of Nurlailah & Setyawan (2019) showed that the application of vermicompost fertilizer at a dose of 13.5 tons ha^{-1} had a significant effect on plant height, namely 182.52 cm.

Dosing vermicompost had a significant effect on the number of leaves. The V_3 treatment produced the highest number of leaves and was significantly different from the V_4, V_2 and V_0 treatments, but not significantly different from the V_4 treatment. The V_0 treatment produced the lowest number of leaves compared to other treatments (Table 2). The highest number of leaves with the V_4 dose was 13.26 strands and the lowest with the V_0 treatment was 11.09 strands. The number of leaves for corn ranges from 10 – 18 strands (Yuliana *et al.*, 2013 *In* Subekti *et al.*, 2007). The higher the plant height, the greater the number of leaves (Fahriani, 2007). In observations from 6 WAP to 7 WAP, the growth in number of leaves occurred significantly in the final vegetative phase. This result is in line with the research results of Mamta & Jyoti (2012) which showed that corn plants given vermicompost grew taller and had more leaves when they reached the final vegetative phase of the plant. According to Nusantara *et al.* (2017) vermicompost fertilizer contains a source of nutrients that can be used to increase plant growth.

Vermicompost dosage had a significant effect on stem diameter. Treatment V_3 produced the largest stem diameter and was significantly different from treatments V_0, V_1, and V_2 but not significantly different from treatment V_4. The V_0 treatment produced the lowest stem diameter compared to other treatments (Table 2). The enlargement of stem diameter is influenced by the nutrient content N, Ca and K contained in vermicompost. The N element is able to stimulate the vegetative growth of plants, especially roots, stems and leaves. Potassium functions as a balance when there is an excess of N, this element increases the synthesis and translocation of carbohydrates so that cell walls are thicker and the stems are stronger. According to Lingga & Marsono (2001) the nutrients contained in vermicompost such as N, P, K, Ca and Mg are really needed by plants for growth, such as roots, stems and leaves.

Vermicompost dosage had no significant effect on leaf area (Table 2). The average leaf area produced ranged from 736.86 cm^2 to 811.49 cm^2. Vermicompost containing N should be able to increase N uptake in plants. Providing N to plants will encourage the growth of organs related to photosynthesis so that it can stimulate physiological and plant tissue growth (Aminah *et al*., 2022). The greater the leaf surface area, the greater the photosynthate can be produced, because this is related to the increase in leaf area which can stimulate a higher rate of photosynthesis resulting in photosynthate being stored in the plant (Adinugraha *et al*., 2016).

The results of the analysis showed that the dose of vermicompost had no significant effect on plant fresh weight. Plant fresh weight in the V_4 treatment was not significantly different from all other treatments (Table 3). The average plant fresh weight produced ranged from 593.53 g to 695.86 g. It is suspected that there is a relationship between water absorption and low levels of soil permeability so it is unable to have an influence on plant fresh weight. Vermicompost should be able to increase the availability of water in the soil so that plant water needs are met which can lead to increased plant fresh weight. According to Lawenga *et al*. (2015), organic materials can improve soil bulk density, permeability, and soil porosity. Soil that has more pores will be able to store more water (Hermawan *et al*., 2021).

Vermicompost dosage had a significant effect on plant dry weight. Treatment V_4 produced the highest plant dry weight and was significantly different from treatments V_2, V_1, and V_0 and not significantly different from treatment V_3. The lowest treatment was produced by treatment V_1 when compared with other treatments (Table 3). The highest plant dry weight in treatment V_3 was 234.2 g and the lowest in treatment V_1 was 180.46 g. In line with research by Libra *et al*. (2018) a vermicompost fertilizer dose of 10 tons ha^{-1} had a significant effect on corn plant dry weight and produced a plant dry weight of 64.6 g per plant. The use of vermicompost fertilizer makes a good contribution to plants and can provide nutrients and other compounds that plants can use to increase plant dry weight (Aprizal *et al*., 2021; Siswanto, 2004).

Table 3. Average yield of corn plants when given a dose of vermicompost

Treatment	PSW (g)	PDW (g)	CLWH (cm)	CLwH (cm)
V_0	593.53	180.46 c	22.93	14.4
V_1	662.6	181.40 c	25.13	16.4
V_2	641.26	191.60 bc	24.19	15.86
V_3	680.53	224.46 ab	24.93	17.26
V_4	695.86	234.20 a	24.99	17.2

Note : Numbers in the same column followed by the same letter are not significantly based on LSD at level 5%. PSW = Plant fresh weight, PDW = Plant dry weight , dan CLWH = Cob length with husk, CLwH = Cob length without husk

Vermicompost dosage had no significant effect on cob weight with husk and without husk. The V_3 treatment for cob weight with husk and without husk was not significantly different from all other treatments (Table 4). The average cob weight with husk produced ranged from 156.53 g to 218.19 g. Meanwhile, the average cob weight without husk produced ranged from 138.46 g to 194.26 g. It is suspected that the P nutrient content in vermicompost is only slightly absorbed by plants during the generative period because it has been applied from the start of planting. The nutrient P is needed in the generative growth phase (Mulyani *et al*., 2007). The addition of organic materials can increase P_2O_5 (Sari *et al*., 2017). The role of P is for the formation of adenosine diphosphate and adenosine tri phosphate compounds which influence energy changes in plants and function in metabolic processes, especially in the seed-filling phase (Wangiyana *et al*., 2010).

The results of statistical analysis showed that the dose of vermicompost had no significant effect on the dry seed weight of the samples. Treatment V_3 was not significantly different from all other treatments (Table 4). The average dry seed weight of the samples produced ranged from 107.13 g to 153.33 g. This result is inversely proportional to the research of Nurlailah & Setyawan (2019), the results of corn weight per plant at a dose of 13.5 tons ha^{-1} produced a weight of 131.3 g and had a significant effect on vermicompost dosage. So as the dose of vermicompost increases, the weight increases but this does not occur significantly. The dry seed weight of corn is influenced by cob size, cob length, and filled seeds (Subekti *et al*., 2007).

Table 4. Average yield of corn plants when dosed with vermicompost

Treatment	CWWH (g)	CWwH (g)	DSWP/samples (g)	DSWP/ha (ton)
V_0	156.53	138.46	107.13	5.94
V_1	192.2	173.53	136.26	7.72
V_2	185.39	164.13	134	6.86
V_3	218.19	194.26	153.33	9.1
V_4	207.06	186.46	150. 40	8.2

Note : Numbers in the same column followed by the same letter are not significantly based on LSD at level 5%. CWWH = Cob weight with husk, CWwH = Cob weight without husk, DSWP/samples = dry seed weight of plant samples, and DSWP/ha = Dry seed weight per ha

Vermicompost dosage had no significant effect on dry seed weight per ha. Observations of the dry seed weight variable in treatment V_3 were not significantly different from all other treatments. The average dry seed weight per ha produced ranges from 5.94 tons ha^{-1} to 9.1 tons ha^{-1}. The research results of Aprizal *et al*. (2021) showed that vermicompost dosing had no significant effect on dry seed weight per ha with the highest yield at a dose of 15 tons ha^{-1}, namely 11.94 tons ha^{-1}. This result is higher when compared to the dose of 22.5 tons ha^{-1}, namely 9.1 tons ha^{-1}. It is suspected that the condition of the research land which is in the degraded ultisol category, low water holding capacity, and low microorganisms means that the nutrients in vermicompost are easily carried away by water. According to Wirosoedarmo *et al*. (2011), aeration and drainage as well as good management will help increase corn crop yields. The average potential yield from the description of the Bisi 18 seed variety can be achieved in the V_3 treatment (22 tons ha^{-1}), namely 9.1 tons ha^{-1} dry shelled, but the potential yield is not achieved, namely 12 tons ha^{-1} dry shelled.

CONCLUSION

The best treatment dose of vermicompost for the growth of corn plants was treatment (22.5 tons ha^{-1}, which gave the best results on the variables plant height (254.85 cm), number of leaves (13.26 pieces), and number of leaves (24.90 mm). The best vermicompost treatment for corn yields, namely the 30-ton ha^{-1} treatment, gave the best results for the plant dry weight variable (234.20 g).

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