The effect of tillage depth and micro-fertilizer addition on the growth and production of cassava (*Manihot esculenta* Crantz) planted in early dry season

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The effect of tillage depth and micro-fertilizer addition on the growth and production of cassava (*Manihot esculenta* Crantz) planted in early dry season

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Abstract. The climate change from the dry season to the rainy season, causes cassava to rot a lot when harvested, this research was conducted in the early dry season by practicing two tillage depths to handle the excessive water around the rooting area, and by addition of micro-fertilizer. This study aimed to determine the cassava growth and yield when planted at the early dry season, combined with tillage depth and micro-fertilizer addition. This research was conducted in South Lampung Regency, Lampung Province, Indonesia. The cutting stems of cassava were planted in the early dry season (May) and harvested in April 2020. The tillage depth consisted of two depths: shallow tillage, above hardpan layer (30 cm), and deep tillage, including hardpan layer (60 cm). Micro-fertilizers were applied with two dosages: without fertilizer (0 kg ha^{-1}) and with fertilizer (40 kg ha^{-1}). Those treatments were arranged factorially (2x2) in Strip Plot Design with three replications. The result showed that deep tillage caused the rotten tubers only 15 tubers compared with the shallow tillage which was 39 tubers. The treatment of micro-fertilizer (40 kg ha^{-1}) on the contrary increased the rotten tubers up to 35 tubers. In general, deep tillage could increase the dry weight of tubers, and micro-fertilizers could increase the fresh weight of tubers.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is an important commodity for food, animal feed, industry, and pharmaceuticals. Unfortunately, the production and harvested area of cassava decline from year to year. In 2017, cassava production in Indonesia was only 19,053,748 tons and a harvest area of 772,975 ha [1]. The decline in cassava production in Indonesia is caused by many factors, such as a decrease in the harvested area, the rarely use of superior clones, less optimum macro, and micronutrient fertilization, less optimal soil cultivation, conditions of soil fertility, etc. In general, farmers usually plow the land of cassava plants by using big tractors with a plowing depth of 25-30 cm [2]. These plowing activities year by year can cause soil compaction, resulting in the formation of a hard layer (*hardpan*). The hard layer causes the soil cannot to be passed by water.

When climate change from dry season to rainy season happens, the plant roots cannot grow properly, the process of water and nutrient absorption is disturbed resulting in inhibited plant growth and production decreases. Therefore, in this study, soil cultivation was carried out with a 60 cm plow depth which is expected can destroy the hardpan layer to make the roots can develop well, so water and nutrient will be better absorbed. Finally, the plants will grow well and production will increase.

The decline in cassava production was also because micronutrients were rarely used. According to Khan et al. [3], the plant needs micronutrients in a relatively little amount, but it is needed for physiological processes. At the beginning of their growth, cassava plants need sufficient water to grow well. This is supported by Isaiah et al. [4], that cassava plants with relatively high rainfall conditions also resulting in high yields of cassava. In addition, Santisopasri et al. [5] stated that adequate water in the first 6 months of its growth can increase the yield and quality of cassava starch. In Lampung, farmers are generally planting cassava at the beginning of the rainy season, between November and December. However, in this study, cassava planting was carried out at the beginning of the dry season accompanied by micro-nutrients and soil depth plow to determine the ability whether at the harvest time in the rainy season the rotten tuber will decline or not.

2. Methods

This experiment was conducted from May 2019 to April 2020 in South Lampung Regency, Indonesia with a soil texture consisting of 36.25% sand, 36.83% silt, and 26.92% clay, so based on the soil texture triangle it is classified as clay loam. The average rainfall in the first 6 months of plant growth was in dry conditions (May-November 2019), which is 32 mm month^{-1}. Meanwhile, the average rainfall in the rainy season (December 2019-April 2020) was 291 mm month^{-1}. The average relative humidity during the planting period was 80.46% with a minimum and maximum humidity of 76.5% and 83.6%, respectively (Figure 1) [6]. The temperature during the planting period was 27.78-29.42°C with an average temperature during the planting period of 28.56°C.

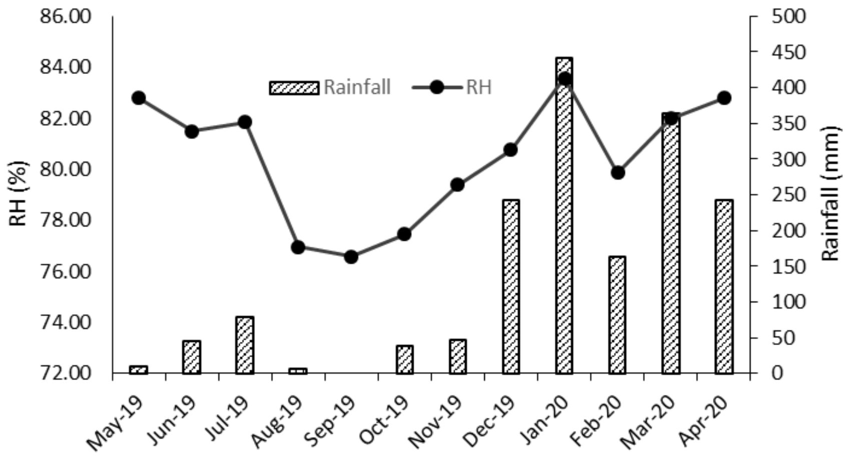

Figure 1. Rainfall and relative humidity during the planting period.

This corresponds to the wet and dry months according to the Schmidt-Ferguson and Oldeman climatic classifications [7]. The tools used were tractors, starch measuring instruments Thai Sang Metric Co. Ltd., cameras, ovens, etc. The materials used were cassava clone BW-1, Urea, TSP, KCl, and ZincMicro fertilizer containing 5,880 ppm Fe, 483 ppm Mn, 198 ppm Cu, 1,368 ppm Zn, 3.34 ppm Co, 4.69 ppm Mo, and 48 ppm B. This experiment was factorially arranged in a Strip Plot Design with 3 replications. The first factor was the depth of plow (P1= 30 cm and P2= 60 cm) and the second factor was ZincMicro dosage (M1=0 kg ha^{-1} and M2=40 kg ha^{-1}).

The parameters were measured in 6, 9 and 11 months after planting (MAP). In 6, and 9 MAP parameters measured were leaf number, and in 11 MAP were leaf number 11 MAP, stem diameter, plant height, stem fresh weight, stem dry weight, leaf fresh weight, leaf dry weight, tuber number, tuber length, root number, tuber number, distribution tuber diameter, tuber fresh weight, tuber dry weight, starch content, and tuber rotten number. The data analysis was subjected to analysis of variance and LSD's Test by using Minitab (Ver.17).

3. Results and discussion

The experiment showed that the growth component of the variable leaf number 6 MAP, leaf number 11 MAP, stem diameter, leaf fresh weight, and stem dry weight varied due to plow effect, while the variable leaf number 9 MAP, plant height, stem fresh weight, and leaf dry weight plow effect showed no variation. The addition of micro-fertilizers showed variations in the variable leaf number 6 MAP, stem diameter, plant height, stem fresh weight, and stem dry weight, while in the variable of leaf number in 9 MAP, leaf number in 11 MAP, fresh leaf weight, and dry leaf weight showed no variation. The interaction between the two treatments only showed variations in the variables of stem diameter, plant height, and stem fresh weight (Table 1).

Table 1. Recapitulation of the mean value of several variables in the growth component of cassava.

Treatment	Growth components								
	LN 6 MAP	LN 9 MAP	LN 11 MAP	SD	PH	SFW	SDW	LFW	LDW
Plow	248.07*	19.27	1251.27**	107.79**	1378.30	39143.00	318282.00*	165197.00*	2336.88
Micro	448.27**	106.67	35.27	518.26**	24163.10**	5273253.00**	8402.00	1571564.00**	33.98
Plow x micro	60.00	60.00	41.67	199.91**	5767.30**	448503.00*	202.00	47935.00	642.56

Note: *=Significant at 5% level, **=Significant at 1% level, LN 6 MAP: Leaf number at 6 months after planting, LN 9 MAP: Leaf number at 9 months after planting, LN 11 MAP: Leaf number at 11 months after planting, SD: Stem diameter, PH: Plant height, SFW: Stem fresh weight, LFW: Leaf fresh weight, SDW: Stem dry weight, LDW: Leaf dry weight.

The effects of P1 and P2 and M1 and M2 to stem diameter, stem fresh weight, and plant height were significantly different between P1 and P2 and M1 and M2. The highest mean values were noted in P1 and M2 (Figure 2).

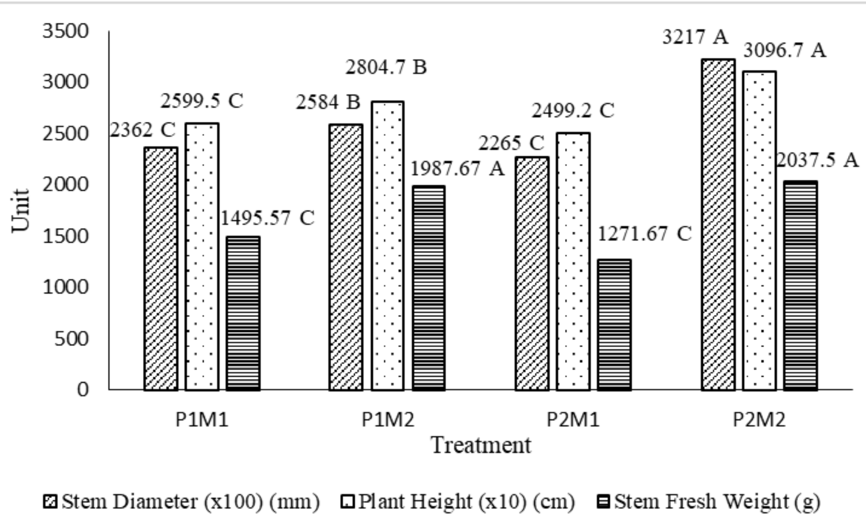

Figure 2. Effect of depth of plow and addition of micro-fertilizers on stem diameter, plant height, and fresh weight of cassava clone BW-1.

Note: numbers followed by the same letter in the same bar showed no significant difference based on the 5% LSD test. LSD (5%) Stem Diameter=186; LSD (5%) Plant Height=193.6; LSD (5%) Stem Fresh Weight=238.60; P1M1:Plow 30 cm with micro-fertilizer 0 kg ha^{-1}; P1M2:Plow 30 cm with micro-fertilizer 40 kg ha^{-1}; P2M1:Plow 60 cm with micro-fertilizer 0 kg ha^{-1}; P2M2:Plow 60 cm with micro-fertilizer 40 kg ha^{-1}.

This result approved that P2, the hardpan layer effect of the soil was reduced and the soil was looser. Such a condition caused the plant to grow better and the absorption of nutrients, maximized. Micronutrients play an important role in controlling plants, namely by helping the cell division process and playing a role in the auxin transport system so that plants added by micro-fertilizers could produce larger stem diameters and higher plant heights than without micro-fertilizers [8]. In other studies the highest plant height of cabbage in the tillage plow (1-4 cm) better than no-tillage [9]. According to [10], adding fertilizer to the soil can increase the number of available nutrients giving to impact the nutrients absorbed. This stem's fresh weight was supported by a larger stem diameter and a higher plant height due to the application of micro-fertilizers.

Table 2. Effects of plow depth and the addition of micro-fertilizers on the leaf number (6 MAP, 9 MAP, 11 MAP), leaf fresh weight, stem dry weight, and leaf dry weight in the cassava clone BW-1.

Plow depth (cm)	LN 6 MAP (sheet)	LN 9 MAP (sheet)	LN 11 MAP (sheet)	LFW (g)	SDW (g)	LDW (g)
30	44.27 a	45.73 a	36.20 b	526.67 b	671.58 a	87.03 a
60	40.20 b	44.60 a	45.33 a	672.33 a	566.64 b	99.51 a
LSD (5%)	3.08	6.24	6.02	119.72	85.85	17.19
Micro fertilizer dose (kg ha^{-1})						
0	39.50 b	43.83 a	41.53 a	587.67 a	457.27 b	92.52 a
40	44.97 a	46.50 a	40.00	611.33 a	780.95 a	94.03 a
LSD (5%)	3.08	6.24	6.02	119.72	85.85	17.19

Note: numbers followed by the same letter in the same column show no significant difference based on the 5% LSD test. LN 6 MAP: Leaf number at 6 months after planting, LN 9 MAP: Leaf number at 9 months after planting, LN 11 MAP: Leaf number at 11 months after planting, LFW: Leaf fresh weight, SDW: Stem dry weight, LDW: Leaf dry weight, LSD: Least Significant Difference.

The average number of leaves in 9 MAP and the leaf dry weight were not significantly different between P1 and P2. However, the leaf number in 9 MAP with the treatment P1 gave the highest value, 45.73 sheets. While the leaf dry weight was highest in P2. There were significant effects between P1 and P2 on leaf number at 6 MAP, leaf number at 11 MAP, leaf fresh weight, and stem dry weight. Leaf number at 11 MAP and leaf fresh weight had the highest values of 45.33 sheet and 672.33 g in P2. On the contrary, the leaf number in 6 MAP and stem dry weight showed the highest values in P1 (Table 2).

Based on the experimental, it was cleared that the difference in plow depth significantly affected the leaf number at 6 MAP, leaf number at 11 MAP, leaf fresh weight, and stem dry weight. The P1 decreased the number of leaves when the plant reached 11 months. On the other hand, at P2, the number of leaves still increased (Table 2). This showed that P2 could make the plant roots grow better so the number of leaves increased significantly.

P1 resulted in a higher number of leaves at 6 MAP (44.27 sheets) than P2 (40.20 sheets). This is probably because the number the leaf fallen on the 30 cm plow was less. After all, the availability of water on the surface of the soil was more available. This is in accordance with the research [12], that on days without rain the water available in the soil layer >20 cm will rise upwards so that in P1 the water content in the soil is still high enough than that of P2.

For the leaf number at 11 MAP, the treatment P2 resulted in a higher leaf number (45.33 sheets) than P1 (36.30 sheets). This is possible because in 11 MAP the water has entered into deeper soil then plants at P2 could absorb more water and the rate of the fallen leaf was less. More pore space on P2 resulted in greater water flux, according to [12] the water flow flux in the root zone is the rate of distribution of rainwater in the root zone. The greater the flow of water flux allows the movement of water and distribution of water to the roots more optimally then plants can grow optimally. The leaf number in the 9 MAP was not affected by P1 and P2. This was possible because in 9 MAP the plant water requirements for P1 and P2 were met and the rate of a leaf fallen on the plants was the same. It resulted that the number of leaves in 9 MAP was not significantly different. However, this study did not observe the rate of a fallen leaf.

The plow depth affected the leaf's fresh weight. At P2, the leaf fresh weight (672.33 g) was higher than P1 (526.67 g). Based on research [10], it was found that tillage could increase net plant^{-1} weight by 75 g greater than without tillage. Then according to [11], soils with large pore spaces could accommodate a greater flux of water flow. However, the leaf dry weight was not in line with the leaf fresh weight, where there is no variation in the leaf dry weight. This was possible because the water content of the leaves in P2 was probably higher than that of the leaves in P1.

The M2 was able to increase the left number in 6 MAP. This is consistent with [12], showing that plants given micro-fertilizer produced more cassava leaves (245 sheets) than without micro-fertilizers. In other commodity research by [13], the application of Zn and Cu micro-fertilizers could increase the production of tea shoots by 4.64 kg plot^{-1} compared to without Zn and Cu micro-fertilizers. According to [14], the application of micro-fertilizers to plants played a role in the formation and preparation of chlorophyll that could increase the number of leaves produced. Plow depth combined with the addition of micro-fertilizers affected the root number and starch content. Meanwhile, tuber dry weight was only affected by plow depth (Table 3).

Table 3. Recapitulation of the mean value of several variables in the production components of cassava.

Treatments	Production components							
	TD	TL	RN	TN	DTD	TFW	TDW	SC	TD
Plow	11.05	0.06	21.60	0.00	232.07	1962042.00	313019.00*	10.53	11.05
Micro	184.44	0.00	180.27	56.07	0.60	4760167.00	23.00	16.17*	184.44
Plow x micro	33.59	2.97	248.07*	52.27	375.00	975275.00	15588.00	12.76*	33.59

Note: * : Significant at 5% level, ** : Significant at 1% level, TD: Tuber diameter, TL: Tuber length, RN: Root number, TN: Tuber number, DTD: Distribution tuber diameter, TFW: Tuber fresh weight, TDW: Tuber dry weight, SC: Starch content.

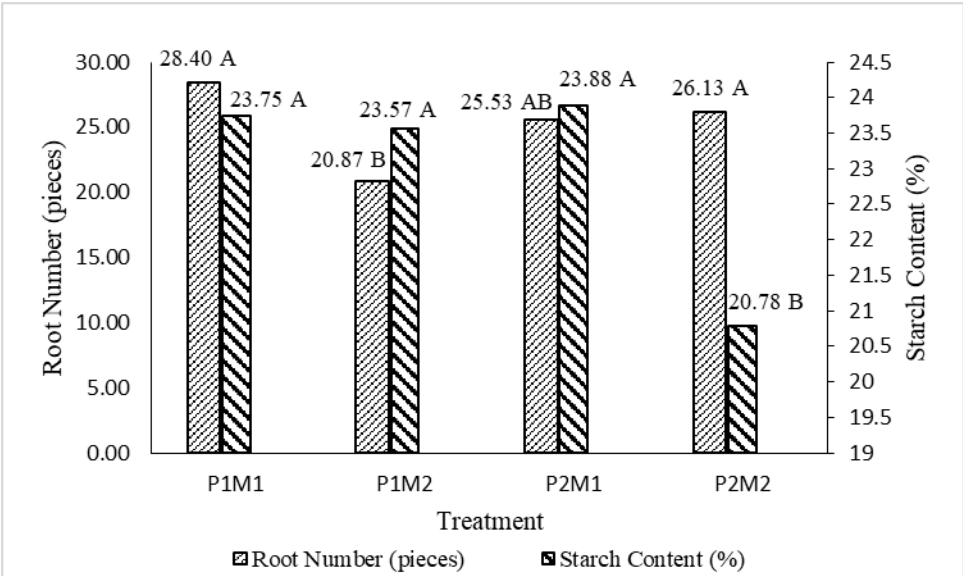

Figure 3. Effect of plow depth and addition of micro-fertilizers on the number of roots and starch content of cassava clone BW-1.
Note:numbers followed by the same font type in the same bar showed no significant difference based on the 5% LSD test. LSD (5%) Root Number= 5.13; LSD (5%) Starch Content= 2.00; P1M1:Plow 30 cm with micro-fertilizer 0 kg ha^{-1}; P1M2:Plow 30 cm with micro-fertilizer 40 kg ha^{-1}; P2M1:Plow 60 cm with micro-fertilizer 0 kg ha^{-1}; P2M2:Plow 60 cm with micro-fertilizer 40 kg ha^{-1}.

The highest mean value of roots was found in P1 with M1, P2 with M2, and P2 with M1 respectively 28.40 pieces, 26.13 pieces, and 25.53 pieces (Figure 3). P2 and M2 affected the number of roots significantly than P1 and M2. It showed that in P2 the soil conditions might be more friable. The result show that the addition of micro-fertilizer 40 kg ha^{-1} at P1 was less effective in increasing the number of roots. It might be assumed the water content in P1 was high that caused the root difficult to develop. This was inversely proportional to the research [15], explained that the Pepper Shrub (*Piper nigrum*) which was added with "Metallic" leaf fertilizer containing micronutrients had a higher average number of main roots compared to those without the addition of Metallic foliar fertilizer.

This research showed that P2 with M1 produced the highest starch content compared to other treatments. This meant that the M2 at P2 caused the plant to absorb more water (Figure 3). This is possible because at harvest time, a P2 the plants still got sufficient water supply from underground, while P1 evaporation still took place while the underground water could not flow up so that the tuber could not develop the starch more. The starch content by the M2 was lower than M1. This is inversely proportional to research [12], that the addition of micro-fertilizer 40 kg ha^{-1} was able to increase the starch content of cassava at the age of 7, 8, and 9 months after planting (MAP). According to Rukmana [16] the starch content in cassava will continue to increase along with the increasing harvest age. According to [17], genetic factors, growing conditions, and harvesting age have an effect on the physical and chemical properties of starch such as granule shape and size, amylose content, and non-starch component.

Table 4. Effects of plow depth and the addition of micro-fertilizers on the tuber diameter, tuber length, tuber number, distribution tuber diameter, tuber fresh weight, and tuber dry weight on the cassava clone BW-1.

Plow depth (cm)	TD (mm)	TL (cm)	TN (pieces)	DTD (cm)	TFW (g)	TDW (g)
30	41.60 a	22.77 a	10.70 a	66.73 a	3223.83 a	816.10 b
60	40.74 a	22.70 a	10.70 a	70.67 a	2862.17 a	1139.12 a
LSD (5%)	3.84	1.91	2.03	8.51	718.57	311.21
Micro fertilizer dose (kg ha^{-1})						
0	39.42 a	22.74 a	9.73 a	68.60 a	2761.83 a	978.98 a
40	42.92 a	22.73 a	11.67 a	68.80 a	3324.17 a	976.23 a
LSD (5%)	3.84	1.91	2.03	8.51	718.57	311.21

Note :numbers followed by the same letter in the same column show no significant difference based on the 5% LSD test. TD: Tuber diameter, DTD: Distribution tuber diameter, TL: Tuber length, TFW: Tuber fresh weight, TN: Tuber number, TDW: Tuber dry weight, LSD: Least Significant Difference.

P2 increased the tuber dry weight of cassava (1139.12 g) compared to P1 (816.10 g). The result approved that P2 gave better soil conditions to the plant to absorb more nutrients (K) to develop the tuber. According to [18], the main uptake of K nutrients by roots is through the diffusion process, where K nutrients move into the roots through soil pores. As a result, the translocation of photosynthate to tubers becomes more optimal. The results of research [19] on potato plants showed that a depth of 15-25 cm plow was able to increase the dry matter content of potatoes by 19.507% compared to the depth of other plows. In addition [20], increasing the depth of the plow up to 40 cm can improve the physical properties of the soil so that yields and crop quality were better.

Rotten tubers are characterized by soft, smelly, and black tuber. P1 indicates a higher number of rotten tuber (39 pieces) than P2 (15 pieces) (Figure 4). This showed that a P2 could reduce the rotten tuber because in the rainy season water could easily penetrate the soil through the soil pores that caused the tubers to be submerged in water for too long which affect the tuber to be rot. Furthermore, M2 (35 pieces) resulted in more rotten tuber than M1 (19 pieces) (Figure 4). This is possible because the addition of a micro-fertilizer could increase the water content in the tuber. This is supported by the data on the tuber fresh weight that M2 (3324.67 g) was better than M1 (2761.33 g), while on the tuber dry weight M2 (976.23 g) was not better than M1 (978.98 g).

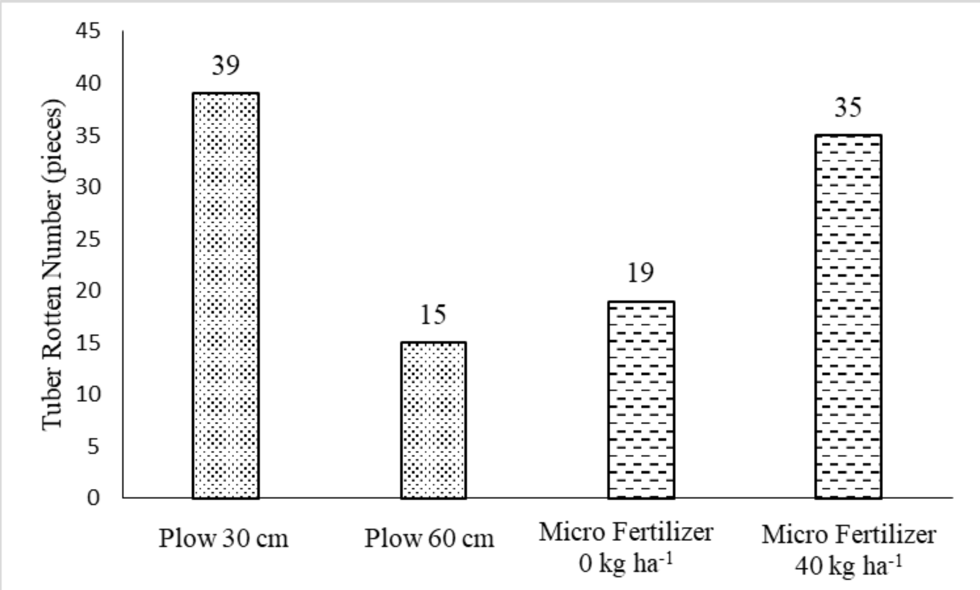

Figure 4. Effect of plow depth, and the addition of micro-fertilizers on the number of the rotten tuber of cassava clones BW-1.

4. Conclusion

- Depth tillage 60 cm could resolve the effect of climate change from the dry season to the rainy season, and therefore could increase the production of cassava.
- Micro-fertilizers could increase the production of cassava even though physiologically would reduce the starch content.

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