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Impact of Organic Amendments and Mineral Fertilizers on the Growth of Vitroplants of the Great Dwarf Cultivar of Banana (*Musa sp*) Installed on a Ferralsol

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the Democratic Republic of Congo, banana is the third largest source of starch after cassava and maize and is the primary fruit crop. However, its cultivation remains secondary due to its high mineral demand, the infertility of tropical soils (ferralsol) and the low income of farmers. The dynamics of mineral elements and the understanding of its influence on crop growth are a necessity for a better use of fertilizers and an optimal crop production. The objective of this study was to evaluate the influence of organo-mineral amendment inputs on banana growth and

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improvement of soil chemical properties. The experiment was set up in a randomised complete block design with 9 treatments spotted 6 times. The treatments consisted of T0 (unfertilized control) ; T1 : 250g NPK (10-20-10) +187.5g urea (46%) ; T2 : 500g NPK (10-20-10) + 375g urea (46%); T3 : 750g NPK (10-20-10) +562.5g urea (46%) ; T4 : 1000g NPK compound fertilizer (10-20-10) +750g urea (46%), T5 : 12 kg (chicken droppings) ; T6 : 18 kg (chicken droppings) ; T7 : 24 kg (chicken droppings) and T8 : 30 kg (chicken droppings) per plant. The vitroplant banana of the great dwarf cultivar were planted and vegetative parameters were observed. Before and during the trial, soil samples were taken from the surface layer for chemical analysis. The results show that the different doses applied to the soil significantly decreased the sodium content (p=0.008) after the trial. On the other hand, similar effects were observed on the other chemical parameters (K^+, Mg^{2+}, Ca^{2+}, Total C and Organic N) before and during the experiment. On the crop, the results show positive effects of organic amendments and mineral fertilization on the development of banana vitroplants. The mineral fertilizer treatments showed a high performance on the crop followed by the manure treatments compared to the control treatment which showed a low performance. However, positive relationships were obtained on soil mineral elements with some crop parameters. Based on these results, it should be noted that the use of organo-mineral amendments contributes to the growth of banana and the reduction of sodium in the soil through the presence of organic matter.

Keywords: Ferralsol; vitroplant; chicken droppings; banana growth.

1. INTRODUCTION

Banana is one of main dietary herbals in developing countries [1]. The Great Lakes region is one of the secondary centers of banana cultivation in the world [2] and is also one of the largest world centers of consumption [3]. Banana is grown in over 120 countries worldwide, with a production of around 86 million tons [4]. It has gained popularity because of its adaptability to different environments and its insurance sales [5]. Its fruit is one of main sources of income and plays an important socio-economic role in tropical countries [6]. In DR Congo, banana is the third source of energy after cassava and maize. But its culture remains a secondary activity in most production areas where there is an unparalleled laxity [7]. The national banana production in Democratic Republic of Congo was down of 75% or leaving two million tons of annual production in 1990 to 500 000 tons in 2002 [8]. Given the importance of its current demand for food in Lubumbashi, local production does not meet population need, forcing it to import from Southern Africa [9]. The low soil fertility, lack of planting material, low income of farmers and viral diseases spread by conventional vegetative propagation practiced by these farmers are the main constraints leading to low yields [8,10]. The results obtained by many researchers [11,12,13] have shown that low levels of yields are also linked to non-application of efficient amendments in culture. Indeed, contribution of amendments improves the soil quality, plant resistance to pests, adaptability of crops to soil and climatic conditions and improving.

Thus, this research has set as objective the assessment of amendments inputs on banana growth and improved chemical properties of a ferralsol.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

This study was conducted in Lubumbashi, in the experimental field of the Faculty of Agricultural Sciences, University of Lubumbashi, Democratic Republic of Congo. The test site is located at 11°39' South latitude and 27°28' East longitude. The Lubumbashi region is characterized by Cw6 climate type according to Koppen classification [14] For rainy agriculture, it includes a normal growth period of 182 days on average and a wet period of about 150 days [15]. This growth period starts at the second half of October to stop in mid-April while the wet period occurs at the first half of November until the first decade of April. The average annual rainfall is 1270 mm, with extreme values of 717 and 1770 mm. The annual average temperature is about 20° [14]. The primary vegetation of the city of Lubumbashi is miombo woodland types.

2.2 Description of the Test

The test focused on vitroplants of the great dwarf cultivar of Banana whose main characteristics are described in Table 1. This cultivar was chosen for its hardiness, its productivity, and the taste quality of its bananas (Table 1).

The experiment was installed on a plot that had just supported another banana crop. After the work of delimitation of the land, the land was prepared manually with the help of hoes. The trial was conducted under a randomized complete block design set up with nine treatments in six replications. The treatment were made up of T0 (unfertilized control) ; T1 : 250g NPK (10-20-10) + 187.5g urea (46%) ; T2 : 500g NPK (10-20-10) + 375g urea (46%) ; T3 : 750g NPK (10-20-10) + 562.5g urea (46%) ; T4 : 1000g NPK compound fertilizer (10-20-10) +750g urea (46%), T5 : 12 kg (chicken droppings) ; T6 : 18 kg (chicken droppings) ; T7 : 24 kg (chicken droppings) and T8 : 30 kg (chicken droppings). Table 2 gives the chemical composition of the hen droppings used. Direct planting of bananas was planted in 60 cm holes at 2.5 x 2.5 m spacing with 1307 plants/ha. Soil amendments were applied at a 10 cm radius around the plant as recommended by [16], which was based on treatments for this study.

Soil samples were taken before and during experiment in the surface layer at a depth of 0-30 cm. A composite sample of the soils for the entire field was taken for each sampling period separately, before being conditioned for chemical properties analysis. These analyses included the determination of nitrogen, potassium, magnesium, calcium, organic carbon and sodium. As the cycle of the cultivar was 14 months, only the vegetation parameters at this stage were assessed and the measurements consisted of the number of leaves, the size of the pseudo-stem, the diameter of the collar, the leaf surface (L*i*0.8; where L: length and i: width of the sheet), and the number of shoots per plant. Statistical processing of the data involved one-factor analysis of variance with Tukey's test for comparison of means at the 5% significance level using Minitab 17 software. After laboratory analysis of the soil samples and statistical analysis, correlations were made between the analyzed soil mineral elements and the vegetative parameters of the crop.

Table 1. Main features of the Great dwarf cultivar (technical data of the cultivar)

Section	Group	U/groupe	Trunkheight(m)	Rusticity	Plan forms	Fruit	Use
Eumusa	AAA	Cavendish	2.1-2.9	Average	Conical	≥17	Dessert

Table 2. Chemical composition of chicken droppings

Chemical components				
P	**N**	**K**	**Ca**	**C/N**
3,25%	5,58%	7,045%	19,20%	5

Fig. 1. Image of banana vitroplant field during experimentation (Credit John Banza M.)

3. RESULTS

3.1 Comparison of the Levels of Soil Mineral Elements before and after the Experiment

The concentration of minerals from soil samples taken before and after experiment were similar except for sodium. Sodium concentration was superior in the soil taken before experimentation than that taken during. The high content of Magnesium is thought to come from the alteration of minerals in the soil and the addition of organic matter. The high content of Magnesium is thought to come from the alteration of minerals in the soil and the addition of organic matter (Table 3).

It was observed that the collar diameter and pseudo trunk size found no significant difference at 30 days after planting. While a significant difference was observed beyond 30 days after planting between fertilized and unfertilized treatments that given the types and doses of fertilizers. The control treatment gave low diameters at the collar and T3 gave the largest diameters at the collar compared to other treatments. For plant height, the T3 treatment had the highest values and the lowest heights were observed on T6 at day 30 and T0 at day 180.However, the number of leaves revealed a significant difference between treatments at 30 and 90 days after planting. The contribution of T3 gives a large number of leaves and the lowest is observed on T6 at day 30 and at day 90 T0. No significant difference was observed at 180 days after planting. A significant difference was observed between treatments for leaf area to 90 and 180 days after planting. The lowest leaf area is obtained on the unfertilized treatment and the highest on T3 at day 90 and T4 at day 180.Regarding the number of offspring, a significant difference between treatments is observed only at the 90th day after planting and the highest averages are acquired respectively by the treatments with mineral fertilizers (class a) and the lowest with the control treatment (class b) (Table 4).

3.2 Correlation between Minerals

The results show a negative correlation between the concentration of assimilable calcium with organic nitrogen and available magnesium. On the other hand, positive correlations are observed for the rest of the soil mineral elements (Table 5).

3.3 Correlation between Growth Parameters and the Concentration of Minerals

The results obtained reveal non-significant positive correlations between growth parameters and mineral concentration. Nevertheless, it is detected negative non-significant correlations between assimilable sodium with the number of leaves and leaf area. The same trend was observed between assimilable calcium and leaf number, leaf area and crown diameter (Table 6).

3.4 Correlation of Different Growth Parameters

Positive correlations between growth parameters are observed in Table 7 below. However, the correlations are significant between the number of leaves with pseudo stem size, collar diameter and leaf area; pseudo stem size with collar diameter and leaf area; and between collar diameter with leaf area.

4. DISCUSSION

After analysis of soil samples taken before and after experiment, higher concentration of a number of mineral elements was observed before experimentation. This observation would be justified by the fact that, the mineral requirement of the banana plant was higher than the doses of amendments applied so that the

Table 3. Comparison of elements before and during the experiment. Mean ± standard deviation

Soil samples	**K^+**	**Mg^{2+}**	**Ca^{2+}**	**Na^+**	**Total C**	**Organic N**
	mg/100g soil			**%**		
Before	31.4±2.7	14.09±3,89	132.94±105.51	2.98±0.37	1.33±0.73	1.59± 0.48
During	22.7±5.7	17.29±4.42	130.53± 23.20	1.76b±0.48	1.74±0.27	2.11± 0.55
P value	0.071	0.372	0.942	0.008	0.170	0.245

Organic and inorganic amendments influence on vegetative parameters

Table 4. Effect of organo-mineral amendments on the growth and multiplication of banana vitroplant

Parameters	Treatments								
	T0	**T1**	**T2**	**T3**	**T4**	**T5**	**T 6**	**T 7**	**T8**	**P**
DC 30	23.20 ± 1.49	27.53 ± 3.49	28.55 ± 3.58	28.97 ± 5.41	27.87 ± 3.27	27.60 ± 3.36	26.50 ± 2.97	28.25±6.15	27.50 ± 4.85	0.41
DC 90	58.2 ± 7.99b	83.83 ±4.2a	94.5±5.86a	95.83 ±13.01a	92.83 ±12.11a	81.67 ±13.54a	79.67 ±10.31a	83±15.5a	85.83±5.56a	0.00
DC 180	102.8 ±16.8b	134±12.70a	143.17±11,2a	153.17±10.4a	152.17±13.7a	141 ±13.78a	139.67±18,4a	145.83±24a	147.67 ±12.19a	0.00
HP 30	19.2±2.58	22.05± 2.40	22.08 ± 2.69	22.33 ± 1.78	21.25 ± 4.10	21.25 ± 4.10	20.08 ± 2.48	21.80 ± 3.09	21.58 ± 2.46	0.51
HP 90	64.2±7.8b	60.33±6.15a	66.42±3.53a	67.50±9.57a	64.00±11.57a	60.00±1.22a	58.33 ± 7.37a	64.17±11.99a	63.00± 8.39a	0.00
HP 180	83.5±16.5b	113.50±10.62a	120.00±7.54a	125.50±8.09a	126.33±10.50a	121.17±17.02a	121.17±14.13a	118.50±19.89a	119.17±11.51a	0.00
NF 30	6.17±0,75bc	6.667±1.21abc	7.333±0.516ab	7.833±0.41a	7.00±1.27abc	6.167±0.75bc	5.833 ± 1.17c	6.33±1.51bc	6.167±1.47bc	0.04
NF 90	12.8 ± 0,41c	13.6±71.37abc	14.17 ± 0.41ab	14.50±0.84a	13.50±1.05abc	13.83±0.75abc	13.0 ± 0.89c	13.17±0.75bc	13.17 ± 1.33bc	0.047
NF 180	20.0 ± 1.27	21.17 ± 1.72	21.67 ± 0.82	22.83 ± 1.17	22.50 ± 1.05	21.33± 1.51	20.67 ± 1.75	20.50 ± 1.87	21.67 ± 2.61	0.08
SF 30	297.3± 39.6	354.07 ± 87.97	436.88 ± 96.03	472.22±139.94	407.07±114.51	382.77±51.19	396.55±46.43	436.03±130.80	456.53 ± 94.44	0.07
SF 90	1424.0±467.7b	2180.3±463.4ab	2458.2±306.1a	2683.1±533.4a	2518.3±656.4a	2164.0±563.6ab	2133.5±490.2ab	2331.8±718.6ab	2489.0±366.2a	0.01
SF 180	3507.3±867.9b	4733.8±612.0ab	5266.5±420.9a	5774.1±690.1a	5939.7±778.5a	5658.3±824.0a	5028.0±1045.2ab	5330.9±1141.8a	5580.5±987.3a	0.00
NO 60	0.00 ± 0.00	1.833 ± 0.983	1.00 ± 0.894	0.67 ± 1.033	1.33 ± 1.21	1.33 ± 1.03	0.83 ± 0.75	0.67 ± 0.82	1.1 ± 0.76	0.06
NO 90	1.33±1.03b	2.83 ±0.75a	2.833 ±0.75a	2.833 ±0.75a	2.83 ±0.75a	2.50±0.55ab	2.667±0.52ab	2.50±1.05ab	2.67±0.82ab	0.047
NO 180	4.41 ± 1.33	4.83 ± 1.47	5.67 ± 0.52	5.33 ± 2.25	5.89 ± 5.00	5.17 ± 1.47	6.33 ± 1.03	4.83 ± 2.04	5.50 ± 2.17	0.52

Legend: T0 : Unfertilized control ; T1 : 250g NPK (10-20-10) +187.5g urea (46%) ; T2 : 500g NPK (10-20-10) + 375g urea (46%) ; T3 : 750g NPK (10-20-10) +562.5g urea (46%) ; T4 : 1000g NPK compound fertilizer (10-20-10) +750g urea (46%), T5 : 12 kg (chicken droppings) ; T6 : 18 kg (chicken droppings) ; T7 : 24 kg (chicken droppings) ; T8 : 30 kg (chicken droppings) per plant. The different letters next to the averages indicate a significant difference after the Tukey test at the 5% probability threshold. DC (cm) : Collar Diameter; HP (cm) : plant height; SF (cm2) : Leaf Area; NF: Number of Leave; NO: Number of Offspring. 30; 60; 90 and 180: days of observation.

Table 5. Correlation between minerals. Mean and P-value

	Total Carbon	Organic Nitrogen	Assimilable Magnesium	Assimilable Sodium	Assimilable Calcium
Organic Nitrogen	0.394				
	0.294				
Assimilable Magnesium	0.218	0.622			
	0.573	0.073			
Assimilable Sodium	0.866	0.005	0.055		
	0.003	0.990	0.887		
Assimilable Calcium	0.796	-0.024	-0.039	0.834	
	0.010	0.950	0.922	0.005	
Assimilable Potassium	0.667	0.618	0.795	0.518	0.367
	0.050	0.076	0.010	0.153	0.331

Table 6. Correlations between functional traits of banana vitroplant and availability of mineral elements. Mean and P-value

	Carbon Total	Organic Nitrogen	Assimilable Magnesium	Assimilable Sodium	Assimilable calcium	Assimilable potassium
NF	0.019	0.680	0.421	-0.213	-0.135	0.433
	0.960	0.044	0.259	0.582	0.730	0.244
HP	0.207	0.408	0.130	0.111	-0.005	0.451
	0.594	0.275	0.739	0.776	0.989	0.222
DC	0.082	0.403	0.159	-0.023	-0.043	0.391
	0.834	0.282	0.683	0.953	0.914	0.299
NR	0.520	0.058	0.088	0,450	0.388	0.561
	0,151	0.882	0.822	0,225	0.303	0.116
SF	0.216	0.494	0.168	0.113	0.094	0.428
	0.576	0.176	0.666	0.772	0,810	0.251

Legends: NF: Number of Leaves; DC: Collar Diameter; HP: height of plants; NR: Number of Rejects; SF: Leaf Area

Table 7. Correlation between vegetative parameters collected during the experiment. Average and P-value

	N F	H P	D C	N R	S F
HP	0.700				
	0.036				
DC	0.747	0.972			
	0.021	0.000			
NR	0.269	0.652			
	0.484	0.057			
SF	0.775	0.948	0.966	0.555	0.481
	0.014	0.000	0.000	0.121	0.190

Legends: NF: Number of Leaves; DC: Collar Diameter; HP: height of plants; NR: Number of Rejects; SF: Leaf Area

plants drew on the soil reserve. Indeed, several researchers such as [12] and [17] showed that low inputs of fertilizers practiced by the farmers contribute to the deterioration of tropical soil properties. So [18] recommend strong fertilizer inputs to improve crop productivity and soil properties. These same authors point out that these contributions should be applied fractionally to facilitate use of mineral resources efficiently by crops. This application helps fight against leaching and evaporation of mineral elements by regional climate constraints [18]. According to [19], cultivation of banana plants is one of largest consumer of minerals, mainly of nitrogen, which is an essential element of biomass playing a key role in the formation of proteins and chloroplasts. Nitrogen is the most consumed mineral element. However, although it exists in three forms (organic, mineral and gaseous), it is mainly the soluble mineral form that is assimilated by the plants, hence the importance of an adequate supply in this form [20]. One of the reasons for the low concentration of minerals available after fertilization would be the influence of the total exchange capacity of the minerals which, according to [21] is dominated by the variable charge of the absorbing complex of the soil. The latter depends on the pH and as the pH of tropical soils is acidic, this leads to the unavailability of minerals despite an adequate supply [22].

A significant difference was observed after analysis of variance for a majority of functional trait of banana based on doses of amendments. A significant difference was observed between treatments receiving fertilizer and the unfertilized control. [23] in a study on organic amendment effects on banana productivity showed that these inflows contributed significantly to the increase in productivity of banana. While [24] on a study of the effects of different doses of nitrogen on the growth of banana observed that such contributions influenced the height of the pseudo stem and collar diameter while the surface leaf and number of leaves were not influenced. The rational explanation for this observation could be that of nitrogen result in the increase and the elongation of meristems. Knowing that the nitrogen is responsible of elongation and cell development [25]. According to this author, the banana is the large crop requires huge amount of fertilizer for growth and productivity (quantity and quality), showing the need of 50 tons of bananas per hectare are 320kg N, 32kg P2O5 and 925kg K2O per year. This fact was also observed by [26]. The contribution of fertilizer influenced the growth and leaf area of banana, while the Number of Offspring is more dependent on the variety. This leaves increase phenomenon results from the release of nitrogen, phosphorus and the assimilation of organic carbon [27,28]. [21] the contribution of organic amendments is more profitable for crops in the tropics. Indeed, by its gradual release of nutrients allows crops to get a high absorption and therefore a higher photosynthetic efficiency reflective performance [29]. While [30] observed a significant increase in productivity of crops gradually associated with intakes of amendments.

Significant positive correlations were found between assimilated sodium and total carbon; between absorbable calcium and total carbon and assimilated sodium; between assimilated potassium and total carbon and with assimilated magnesium.This situation is linked to the synergy between these elements. These results are similar to those obtained by [2] after an analysis of the mineral concentration of some banana organs and the concentration of soil elements. The same finding was observed by [31] having obtained high and almost similar concentrations of magnesium and potassium evidence that these elements are positively correlated. Then, a study by [32] showed that the increase in calcium concentration, unlike that of potassium as a function of age of the banana. This phenomenon leads to a strong accumulation of calcium at the expense of potassium, it first becomes the most abundant element in the tissue with 1335.33 mg/100 g dry matter replacing potassium [33]. The positive correlation between growth parameters and availability of minerals could be explained by the fact that the minerals have a beneficial effect on the growth of crops. Thus [17] achieved an increase of various growth parameters based on increasing inputs of chicken manure. And [3] proved that fertilization contributes significantly to improve growth in comparison with a non-amended. For [34] the main cause of declining banana yields in tropics would be the soil infertility and non-use of fertilizer either organic or inorganic showing the correlation between these two factors. Several studies such [35,36] reported that elements boost the physiological condition of plants and encourage growth. However, [36] reported that although the inputs of fertilizers we tune influence on crop growth, there are other bodies that are genetic and whose amendments have no influence [37] demonstrate that the addition of amendments effectively contributes to better development of crops by the nitrogen contained in these fertilizers. Thus [38] and various studies [39,40] on the evaluation of banana growth variables identified as nutrient status of soil significantly influence the growth and development of banana.

Positive correlations were observed between the different vegetative parameters. It should be noted that a very significant positive correlation was obtained between the size of the pseudo stem and collar diameter, this result corroborates that obtained by [9] showing that the growth evolution curve of these two parameters had the same trend. This same study found that the leaf area was strongly linked to the emergence of new leaves on the plant results justify the significant positive correlation obtained in this study [23] demonstrated that all parameters were influenced by increasing inputs of fertilizers, thus had a positive correlation between them. [24] obtained positively correlated behavior between the different parameters, unlike our results, the reason for this discrepancy could be the non-accounting for nutritional interaction on crop behavior. In a study on agronomic performance of banana, [41] have achieved very significant positive correlations between the collar diameter and number of leaves, rational explanation for these results is the choice of materials used and the observation time.

5. CONCLUSION

The doses applied did not significantly improve the chemical properties of the soil. The results show that mineral fertilizer and manure applications are effective in improving plant development of banana trees. However, it was observed that crown diameter and pseudo stem size showed similar effects at 30 days after planting. Then significant effects were observed beyond 30 days of planting. The low diameter values were on the control and contribution of 750g NPK (10-20-10) +562.5g urea (46%) gave the largest diameters at the crown. This same treatment had the highest values on the plant height, and low heights were observed on treatment with 18 kg of chicken droppings at day 30 and on the unfertilized control at day 180. The treatment witch 750g NPK (10-20-10) +562.5g urea (46%) was among obtaining many leaves and the lowest was observed on the treatment witch 18 kg of chicken droppings at day 30 and on the unamended control at 90 days after planting. The amended treatments resulted in plants with a large leaf area compared to the unamended control. Regarding the number of offspring, a significant difference between treatments was observed only at day 90 after planting and the treatments with mineral fertilizers showed a high number of offspring followed by the manure treatments and the lowest with the control treatment. In the context of this study, 750g NPK (10-20-10) + 562.5g urea (46%) per plant would be recommendable.

Ethics: The authors declare that they have no conflicts of interest in this article. The data are original and from experiments conducted by the Authors of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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