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Yam production on the sandy soil of Bateke Plateau (DR Congo)

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ABSTRACT
Objectives: Yam contains approximately four times as much protein as cassava, and is the only major root crop that exceeds rice in protein content. In DRC, it represented one of the basic foods for the equatorial forest and savannas population; however, its production remains too low for many reasons such as soil fertility. Soil amendment is not a common practice in yam cultivation in DRC. This study evaluates the effect of the amendment of sandy soil on yam production. The pH, organic matter content and the main soil nutrients were analysed.
Methodology and Results: The micro sets of both species of yam: *Dioscorea alata* and *Dioscorea rotundata;* 3t/ha of lime, 1,25T/ha of organic matter (droppings of hen) and, 125 T/ha of mineral fertiliser NPK (17-17-17) were used as amendments. Four experiments were carried out concurrently for two consecutive years. Lime application increased the weight of root tuber of *D. rotundata* by 3 times, the organic matter by 2.5; the combination of both by 3.5 and NPK enhanced the weight by 8. According to *D. alata*, 2.2 increased the weight of root tuber by organic matter.
Conclusions and application of results: The application of fertiliser improved yam production; the weight of root tuber was increased 8 times. As the amendments enhanced the agronomic yield, it remains to look into the economic cost-effectiveness before requesting the extension service to inform the stakeholders.
Key words*:* Yam, Sandy soil, Lime, Organic matter and Inorganic fertiliser.

RÉSUMÉ
Objectifs **:** L'igname contient 4 fois plus de protéine que le manioc et, c'est la seule plante à tubercule qui dépasse le riz en protéine. En RDC, elle a constitué l'un d'aliments de base des populations de la forêt équatoriale et de savane; mais, sa production est très faible pour des raisons multiples dont la fertilité de sol. La culture d'igname (*Dioscorea spp)* en RDC ne bénéficie aucun amendement des sols; cette étude évalue la réponse des sols sableux et celle d'igname aux amendements appliqués. Les analyses de sols ont porté sur l'acidité, la matière organique et les principaux éléments fertilisants
Méthodologie et résultats : Les micros fragments prégermés de deux espèces d'igname : *Dioscorea alata* et *Dioscorea rotundata* ont été cultivés. La chaux (3T/ha), la matière organique (la fiente de poule, 1,25T/ha) et, l'engrais minéral NPK 17-17-17 (125 kg/ha) ont servi

d'amendements. Quatre expérimentations ont été menées concomitamment pendant deux années consécutives. L'application de la chaux a augmenté le poids des tubercules de *rotundata par 3,* la matière organique par 2,5 ; la combinaison des deux par 3,5 et le NPK par 8; quant à *alata*, son poids est multiplié par 2,2 par la matière organique.
Conclusion et application des résultats **:** L'apport en nutriments par des fertilisants a corrigé les déficiences nutritionnelles, améliorant ainsi le poids des tubercules. L'application d'amendements a amélioré les rendements agronomiques ; il y a lieu de se pencher sur la rentabilité économique avant de vulgariser les résultats auprès des paysans.
Mots-clés: Igname, Sol sableux, Chaux, Matière organique, Engrais minéraux.

INTRODUCTION

Yam *(Dioscorea sp)* is well known to the people of all tropical countries since the earliest times. Before the introduction of cassava and sweet potato in DR Congo, yams were the staple food of the populations of the great equatorial forest and its neighbourhood; it was found spontaneously throughout the territory, mainly in forest regions (Van Den Abeele and Vandenput, 1956). Nowadays, yam is commonly eaten all over DR Congo; but its production is very low for multiple reasons. The lack of planting materials, the cultivation techniques used as well as the fertility of the soil are the main constraints that do not allow an increase in the production of this crop, as has been reported elsewhere by Carsky *et al.* (2010). This situation leads to low consumption of yams on the one hand, and a decrease in production by farmers on the other hand (Etim et al., 2013). This is how the production of this food has remained low and the price of this commodity remains high on the Congolese market. The nutritional values of yam are well known: it is a good source of energy, vitamins, minerals and phyto-nutrients like beta-carotene. Its composition is similar to that of the potato, but with a higher nitrogen content (Bhandari *et al.* 2003; O'Sullivan, 2010). It can advantageously replace the potato in tropical countries. It contains approximately 4 times more protein than cassava (Lebot, 2009) and it is the only tuber that exceeds rice in protein in a well digestible proportion (Bradbury and Holloway, 1988). Yams are consumed in several forms apart from fresh boiled tubers. There is the production of flour, dried or frozen chips, drinks, mash; all these products increase the added value of these crops. The cultivation techniques used for the production of yam commonly consumed in DRC not include any amendment. However, the soils of the DRC are generally of low fertility (Sys 1971). And, it turns out that there is generally very little information on the relationship between soil fertility and yams (O'Sullivan, 2010) Thus, it appears more than necessary to focus first on cultivation techniques and improving the fertility of the soils which constitute the substrate on which plants develop. Commonly cultivated yam varieties should be used in order to assess their response to the application of amendments in the area where the experiment is taking place: the Bateke Plateau. This area, which covers more than 7000 km2, is covered with sandy soils; it is located in the hinterland of the city of Kinshasa. The use of both mineral and organic amendments on these sandy soils would improve the productivity of these soils and, the yam yield would be higher. The objective of this study was to assess the response of yam cultivation to amendments that are applied to the sandy soil of the Bateke Plateau.

MATERIAL AND METHODS

Two variety of yam: *Dioscorea alata* and *Dioscorea rotundata* were used in this study. The tubers were cut in the form of micro fragments of 30 to 40 grams. These were pre-germinated using the minisett technique advocated by IITA (1985). Recovery on the 21st day after planting and on the 28th day was observed. The seedlings were transported to the field at the Bateke Plateau for establishment in September 2018, and the harvest took place in August 2019. The experiment was repeated in September 2019, and the harvest took place in August 2020. Four experiments in completely randomized blocks with 3 repetitions were carried out concomitantly. Each block represented a repetition with all the treatments related to the experiment. The area of the elementary plots was 6m2 and the spacing between plants was 1m x 1m as recommended by Landon (1991). The amendments used consisted of limestone powder (lime), organic matter (chicken droppings) and mineral fertilizer (NPK 17-17-17). They were applied all at once a week before the establishment of the seedlings. The doses used were equivalent to those given below: 1.25 T / ha for organic matter, 3T / ha for lime and, 125 kg / ha for NPK. The different experiments are as follows:

- 1st experiment: test with the soil in place as a reference;
- 2nd experiment: lime-based test;
- 3rd experiment: test based on organic matter;
- 4th experiment: combined test with the three different amendments (lime, organic matter and mineral fertilizer).

The various cultural operations carried out were as follows: weeding was done three times from the 5th week after transplanting, staking in the 3rd week after transplanting the seedlings and hilling three months after transplanting. Soil samples were taken from the experimental field at depths of 0-15 cm and 15-30 cm before seedling establishment and after harvesting of tubers. They were analysed in the Laboratory of Soil Science of the Faculty of Agricultural Sciences of the University of Kinshasa for the pH, organic matter, exchangeable bases, cation exchange capacity, available phosphorus and nitrogen, according to the methods and procedures recommended by Van Ranst *et al.* (1999). The data from the various experiments were statistically analysed. Analysis of variance was the primary procedure used to test the significance of differences between treatments; the latter were determined using the ANOVA and the means of the treatments compared by the smallest significant difference at the threshold of 5%. The means were significantly separated using the test of Duncan (1955) "Duncan's new multiple range test", modified by Wikipedia on May 3, 2016.

RESULTS AND DISCUSSIONS

Soil analysis: It appears from this table that the soil of the Bateke Plateau is really sandy and its pH is acidic. The content of various nutrients is very low, including organic matter. The limed land was able to maintain a pH that approached the optimum after harvesting the tubers; whereas the organic matter content is at an average level. Liming thus improved certain properties of the soil, which would make it more productive.

Table 1: Results of soil analyses before and after planting.

Parameters observed		**Analyses before**	**After planting**	**After harvested**
Granulometric (%)	Sandy	71,4	-	-
	Silt	22,2	-	-
	Clay	6,4	-	-
pH (water)		4,8	6,5	5,8
C (%)		1,86	-	5,20
N (%)		0,09	-	-
O.M.		3,20	-	8,96
P total (ppm)		0,51	-	-
Ca^{++} (méq/100g)		0,44	1,25	1,05

Legend: C = carbon, N = nitrogen, O.M. = Organic matter, P = phosphorus, Ca = calcium, ppm = parts per million, meq = milliequivalent, - = no analysis performed.

Experiments: The results of the various experiments are shown in the following lines. They are classified according to the amendment considered to be the basis of the trial. The results of the first trial that had as a base the existing soil considered as a control are shown in Table 2.

Table 2: Effect of amendments on average tuber weight.

	Mean weight of tubers root (kg)	
Treatments	***D. rotundata***	***D. alata***
control	0,18 a	2,86 a
Lime	0,51 c	3,10 b
O.M	0,30 b	3,57 c
NPK1	1,59 d	4,38 d
PPDS (5%)	0,11	0,13

NB: In a column, the figures followed by the same letters are not significantly different at the 5% threshold.

It can be seen from Table 2 that the use of amendments resulted in an increase in tuber root weight of both varieties of yam compared to the control. Referring to the control as the basis for the productivity of these soils, Figure 1 has been drawn up. It makes it possible to assess the effect of amendments, their impact on the yield of the yam. From Figure 1, it appears that except the increase in tuber root weight due to the use of amendments, the increase is not the same. *D. rotundata* is more responsive to lime than *D. alata*. Organic matter outperformed lime for the Alata species; statistical analyses confirm this observation. In addition, NPK multiplied the weight of tubers by 8.8 Kgs for rotundata, and only 1.5 for Alata.

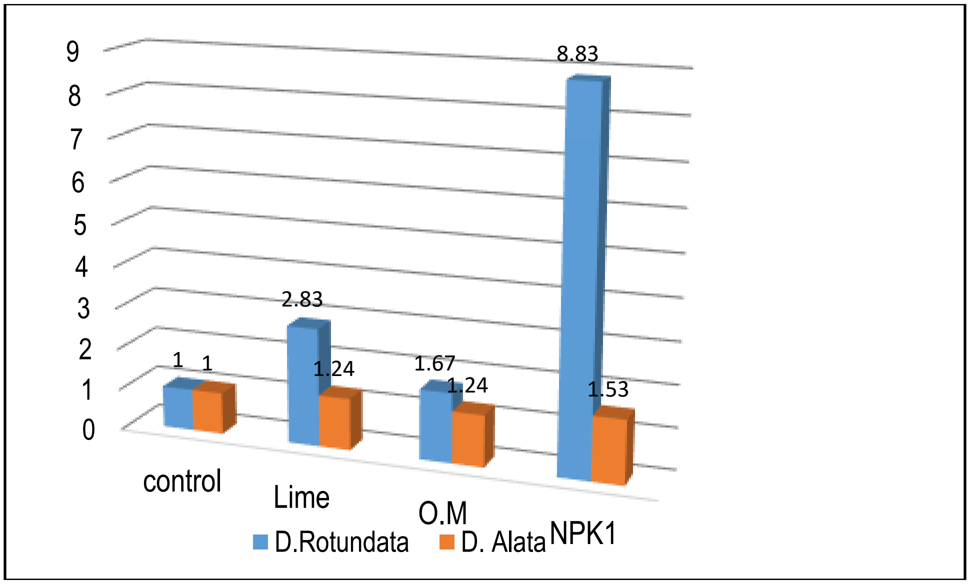

Figure 1: Effects of amendments on tuber root weight *gain (Kgs)*

The two species of yam did not have the same reaction following the application of the various amendments used. This behaviour would be due to their origin. The forest species, *D. alata* is unaffected by soil acidity, while the savanna species, *D. rotundata* is well affected. Indeed, forest areas generally have acidic soils and the species that grow there are only slightly affected by the acidity of the soils. Table 3 and Figures 2 and 3 show the results of the trial, which considered lime as the basis for the amendments. Lime was used alone or in combination with other amendments. From Table 3 it can be seen that the use of lime allowed an increase in the weight of the tubers root. The combination with NPK gave larger tubers compared to the control, 0.9 and 5.8 kg against 0.18 and 2.86 kg, respectively for *D. rotundata* and *D. alata*. Considering again the control as a reference, figure 2 has been drawn up. Table 3. Weight of tubers (kg) induced from amendments combined with lime.

Table 2: Effect of amendments on average tuber weight.

Treatments	**Average weight of tubers root (kg)**	
	D. rotundata	***D. alata***
control	0,18 a	2,86 a
Lime	0,51 b	3,10 b
Lime + O.M	0,63 bc	4,26 c
Lime + NPK1	0,74 c	5,64 d
PPDS (5%)	0,12	0,15

NB: In a column, the figures followed by the same letters are not significantly different at the 5% threshold.

Figure 2, which illustrates impact of using lime as a base amendment compared to the control, shows the rate of increase in tuber root weight. As a result, the use of lime initiated an increase in the weight of tubers, regardless of the species of yam considered. D. rotundata, which produces small tubers, responds better to the use of lime on this acidic sandy soil of the Bateke Plateau than *D. alata*, which is bulky.

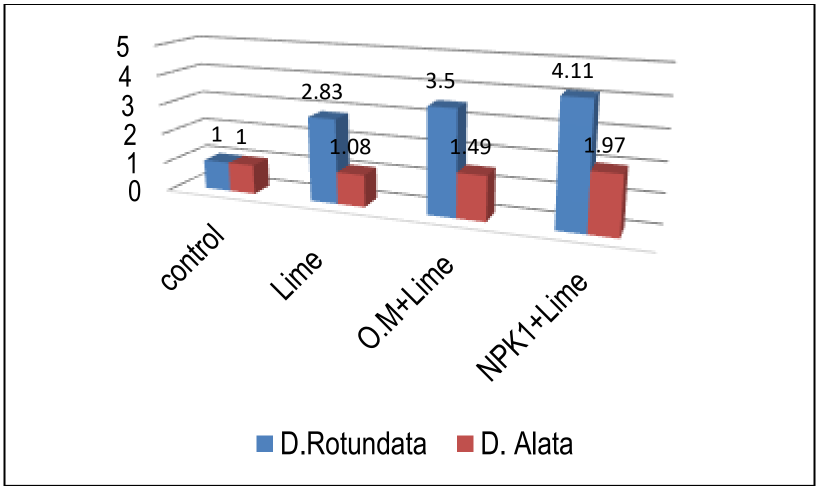

Figure 2: Impact of lime on the increase in tuber weight (Kgs) compared to the control.

Furthermore, considering lime as the basis of the amendment system, Figure 3 has been drawn up. It can be seen from Table 3 that the use of lime increased the weight of yam tubers of two species. The average weight of tubers increases from 0.18 to 0.5kg and 2.86 to 5.8 kg respectively for *D. rotundata* and *D. alata*. The combination of amendments also increased the weight of the tubers. However, the two species did not respond in the same way to the amendments. Indeed, from Figure 2, it appears that the increase in weight resulting from the use of lime is far more marked with *D. rotundata* than with *D. alata*. Compared to the control, the application of lime increased the tuber weight of *D. rotundata* by 2.83 times, while that of *D. alata* was only 1.08. The combination of lime with NPK at the rate of 125 kg / ha increased tuber weights of 4.11 and 1.97 times, respectively for *D. rotundata* and *D. alata.*

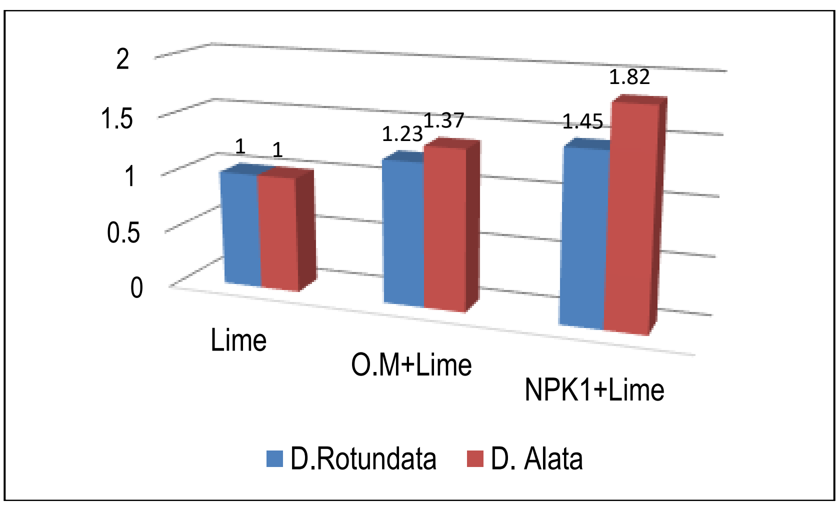

Figure 3: Impact of lime taken as a control on the gain of tuber weight (Kgs).

Considering the use of lime as a reference shown in Figure 3, the combination of the latter with organic matter or NPK initiated the increase in tuber weight differently than that reported in the previous lines. The effect of lime appears to be higher for *D. alata* than for

D. rotundata, the most striking combination was that with NPK, however the weight of the tubers could not be doubled.

The results of the 3rd trial which considered organic matter as a basis for amendment are shown in table 4 and in Figures 4 and 5.

Table 4: Effects of Organic Matter on increasing tuber weight.

Treatments	**Mean weight of tubers root**	
	D. rotundata	***D. alata***
Control	0,18 a	2,86 a
Lime	0,30 ab	6,34 e
Lime + O.M	0,63 c	4,26 c
Lime + NPK1	0,41 b	4,07 b
PPDS (5%)	0,13	0,17

NB: In a column, the figures followed by the same letters are not significantly different at the 5% threshold.

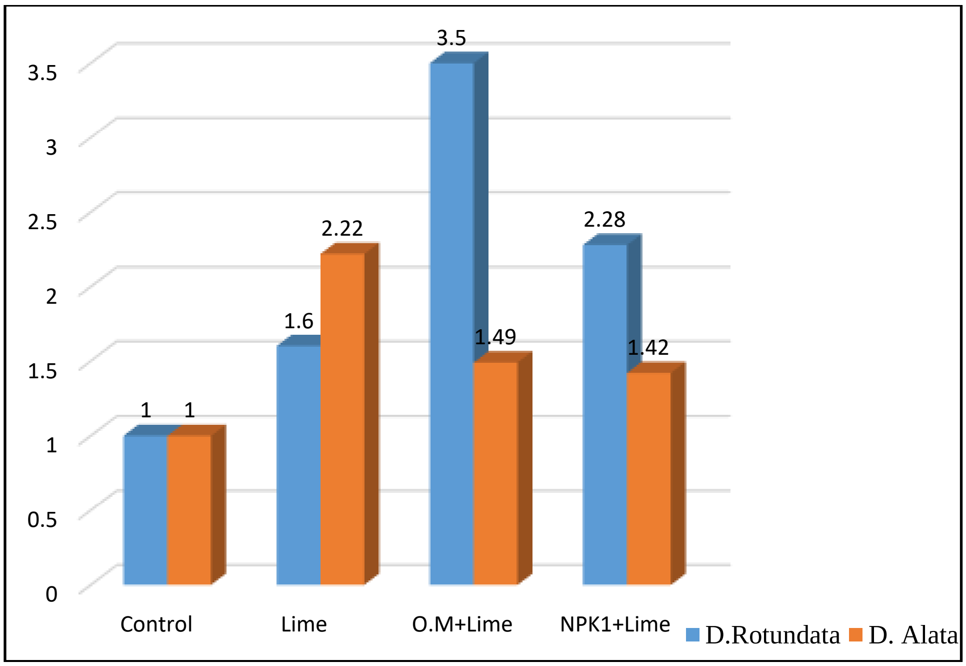

Figure 4: Impact of Organic Matter on the increase in tuber weight compared to the control.

Compared to the control, to use of organic matter allowed an increase in tuber weight ranging from 1.7 to 3.5 and from 1.2 to 1.8 respectively for *D. rotundata* and *D. alata*. The response to organic matter was more noticeable for D. rotundata. In addition it appears that this response is far clearer when organic matter is used in combination with lime, the weight of tubers is multiplied by 3.5.

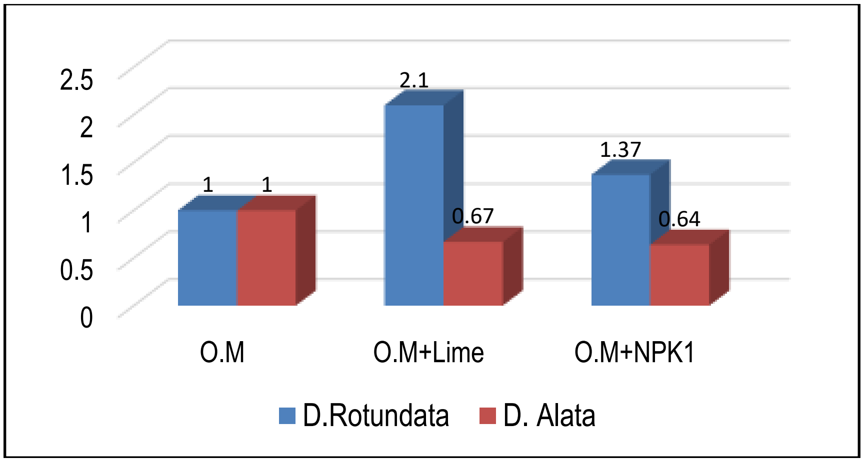

Figure 5: Impact of Organic Matter considered as a control on the increase in tuber weight. Considering organic matter as a benchmark, it appears that its use leads to a slight increase in tuber weight.

It is in combination with lime that the weight of the tubers is multiplied by more than 2 for D. rotundata. For all other combinations the weight gain was less than 1.7 for the two species of yam used. Table 5 shows the various experiments relating to the application of amendments to the sandy soils of the Bateke plateau. It appears that the amendments applied have all improved the productivity of this soil. The combination of amendments has given the best results.

Table 5: Impact of the combination of different amendments on the increase in tuber weight.

Treatments	Mean weight of tubers root kg)	
	D. rotundata	*D. alata*
Control	0,18	2,86
Lime	0,51	3,10
O.M	0,30	3,57
NPK1	1,59	4,38
Lime + O M.	0,63	4,17
Lime + NPK 1	0,74	5,64
O M.+ N PK 1	0,41	4,07
Lime + O .M + NPK 1	1,78	6,11

DISCUSSION

The soil where this study took place is sandy, light soil; it constitutes a favourable substrate for the production of yam, as the tubers can easily develop, and thus, the potential of each species used would have been well expressed. Indeed, Agbede (2005) reported that soil density was negatively correlated with tuber length and yam yield. In addition, the density of 1m x 1m used for the plants was the best one responded in tropical conditions for a better evaluation of different yam species as pointed out by King and Risimeri (1992) and Suja *et al.* (2003). The results of this trial are restructured in Figures 6 and 7 for better interpretation of the data and, good decision making for further research work. Figure 6 illustrates the behaviour of Rotundata following the various amendments applied; while Figure 7 refers to Alata. The trend of the curve in figure 6 is more exponential, while that of figure 7 is more or less linear. The shape of these curves explains how each of the 2 yam species reacts to the application of amendments. The curves of the yam response to the different amendments show the level of receptivity of each species. This demonstrates the ability of each plant species to react to soil amendments.

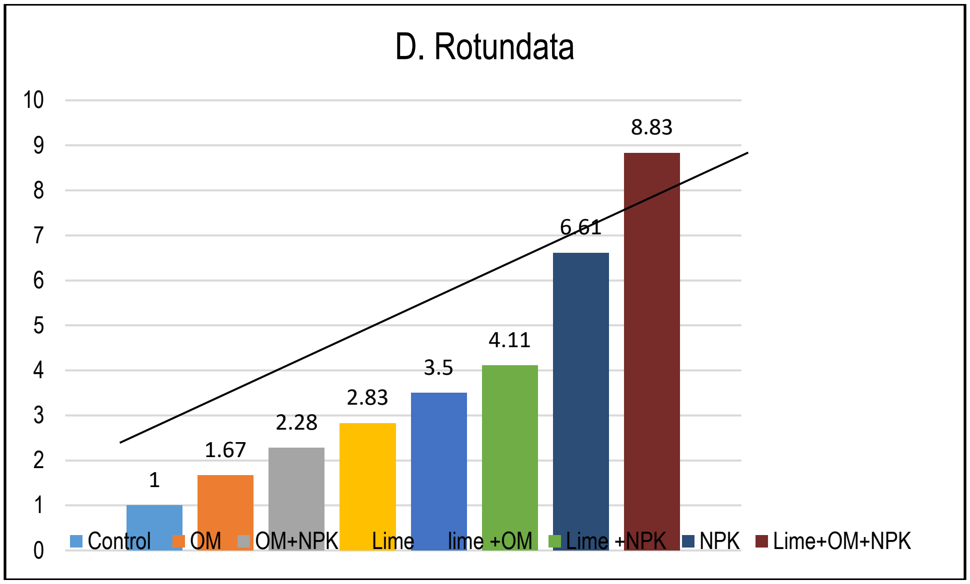

Figure 6: Impact of amendments on the weight increase of Rotundata tubers

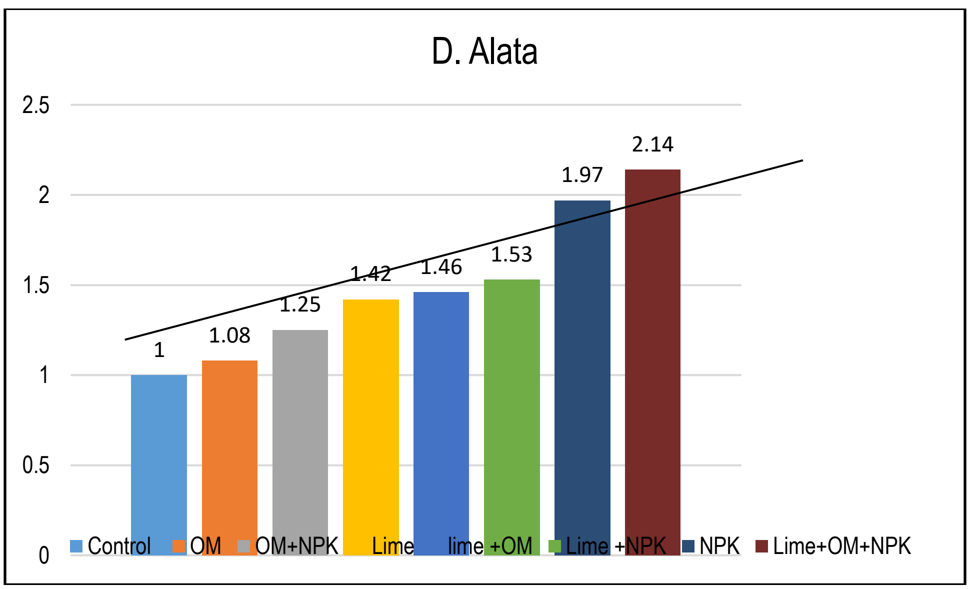

Figure 7: Impact of amendments on the weight increase of Alata tubers

Data in figures 6 and 7 show the efficiency of combining amendments. The combination of lime, organic matter and NPK resulted in a weight increase of 8.83 and 2.14 respectively for *D. rotundata* and *D. alata*. The weights of the tubers were very high by combining the different amendments used.

CONCLUSION AND APPLICATION OF RESULTS

As noted by Asher, Grundon and Menzies (2002), the nutritional deficiencies of this acidic sandy soil were alleviated by nutrient inputs. This is how the application of mineral fertilizers helped to improve the weight of the tubers; it is one of the ways to achieve it. Another avenue is to use organic matter in the latter contains an appropriate balance of the required nutrients. For these applications, liming acidic soils is an urgent necessity. However, if the application of amendments improves the weight of the tubers, hence the agronomic yields for yam; economic profitability should be considered by referring to the costs of the different amendments to be used, the adequate doses for profitable production. In addition, large tubers could pose some market problems; their transformation into flour would constitute a possible solution. By the way, the economic cost-effectiveness should be evaluated. Therefore the stakeholders can be informed thought the extension service on the results of this trial.

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