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Combined effect of lime and castor leaves (*Ricinus comminus*) on some physico-chemical parameters of sandy soil and on the production of Okra (*Abelmoschus,esculentus, M*) in Kinshasa (DR Congo)

Jeancy Ntuka Luta., Blaise Lunjwire Ntwali, Alasca Ekuya Lombolu., Paul Mafuka Mbe-Mpie.

University of Kinshasa, Faculty of Agricultural Sciences, Laboratory of Soil Science, BP 117 Kinshasa XI (DRC). Corresponding authors : jeancyntuka@gmail.com, mpmafuka2@gmail.com

Abstract

Objective: This work deals with the improvement of the productivity of sandy and acid soils of the city of Kinshasa (DRC) by the use of lime and biomass of castor leaves (*Ricinus comminus*). The okra crop was used to assess the performance of the applied amendments.

Methodology and results: To evaluate the combined effect of lime and different doses of castor leaves in the sandy soil of Kinshasa, an experiment was conducted at the Pôle Expérimental Horticole of the Faculty of Agronomic Sciences, within the campus of the University of Kinshasa.

The combined effects of lime and castor leaf biomass on edaphic parameters are evaluated in comparison with those of the control soil (lime) during two cropping seasons.

The results of this study showed that the combined application of lime and castor leaves positively influenced the soil response, the increase in soil organic matter content, the Cation Exchange Capacity and consequently the growth and production of okra in the first cropping season. In the second cropping season, a decrease in cation exchange capacity and soil organic matter content was observed for all treatments. The control (lime) showed the closest pH to neutrality.

Conclusion and recommendation: This study shows that lime cannot be used alone for production. Apart from its role in correcting acidity and increasing cation exchange capacity, it does not provide primary mineral elements such as N, P, K except calcium in the soil which the plant does not use in large quantities. The results of these investigations showed that the residual effects are not evident on the growth and yield of okra. We recommend the following: when applying lime, it should be accompanied by either chemical or organic fertilizers to improve soil productivity and crop yield.

Key words: Lime, castor leaves, pH, Organic matter, CEC, sandy and acidic soil, Okra.

Résumé

Effet combiné de la chaux et des feuilles de ricin (*Ricinus comminus*) sur certains paramètres physico-chimiques des sols sableux et sur la production de gombo (*Abelmoschus esculentus, M*) à Kinshasa (RD Congo)

Objectif : Ce travail traite de l'amélioration de la productivité des sols sableux et acides de la ville de Kinshasa (RDC) par le recours à la chaux et la biomasse des feuilles de ricin (*Ricinus comminus*). La culture de Gombo a été utilisée pour apprécier les performances des amendements appliquées.

Méthodologie et résultats : Pour évaluer l'effet combiné de la chaux et différentes doses des feuilles de ricin dans le sol sableux de Kinshasa, une expérience a été conduite au Pôle Expérimental Horticole de la Faculté des Sciences Agronomiques, au sein du campus de l'Université de Kinshasa.

Les effets combinés de la chaux et de la biomasse des feuilles de ricin sur les paramètres édaphiques sont évalués par comparaison à ceux du sol témoin (la chaux) pendant deux campagnes culturales.

Les résultats de cette étude ont montré que l'apport combiné de la chaux et des feuilles de ricin a influencé positivement la réaction du sol, l'augmentation de la teneur de la matière organique du sol, la Capacité d'Echange Cationique et par ricochet la croissance et la production du Gombo à la première saison culturale. A la deuxième saison culturale, une baisse de la capacité d'échange cationique ainsi que celle la teneur en matière organique du sol a été observée pour tous les traitements. Le témoin (la chaux) a présenté le pH le plus proche de la neutralité.

Conclusion and recommandation : Cette étude montre que la chaux ne peut pas être utilisée seule pour la production. Hormis son rôle sur la correction de l'acidité et l'augmentation de la capacité d'échange cationique, elle n'apporte pas les éléments minéraux primaires comme le N, P, K excepté le calcium dans le sol que la plante n'utilise pas en grande quantité. Les résultats de ces investigations ont montré que les effets résiduels ne sont pas évidents sur la croissance et au rendement du gombo.

Nous recommandons ce qui suit : lorsque l'on applique la chaux, elle doit être accompagnée des engrais soit chimique ou organique pour améliorer à la productivité de sol et le rendement des cultures.

Mots clés : Chaux, feuilles de ricin, pH, Matière organique, CEC, sol sableux et acides, Gombo.

Introduction

The greatest challenge for the agricultural sector in the 21st century is to increase food production to satisfy the rapidly growing human population, especially in urban areas. The agricultural production sector must simultaneously address two objectives: the first is sustainability, which involves soil and water conservation; the second is increasing production to satisfy the ever-growing population. In general, the majority of agricultural production in tropical soils is still based on the traditional shifting cultivation system (Mulaji, 2011); thus, sustainable management of soil fertility in these areas is still relevant. However, the market gardening system is no longer shifting, it is sedentary. The targeted agricultural speculations are practiced in the same place for years. This mode of agricultural practice requires a continuous supply of nutrients for the plants that follow one another in the same beds, since each harvest exports a certain number of mineral elements that the following crops need.

Since agriculture in the tropics is essentially rain-fed and does not require substantial soil amendments, it is dependent on climatic hazards, such as heavy rainfall or unusual drought. In addition, the edaphic conditions: soil acidity and low organic matter content constitute challenges to be met.

Most of the soils in the Democratic Republic of Congo, and particularly those in the city of Kinshasa and its surroundings, are sandy. These soils are characterized by their high acidity, their pH fluctuates around 5, and their low content of major fertilizing nutrients is linked to a cation exchange capacity that is often less than 16 meq/100 g of soil (Roose, 1980). These soils have a sandy texture (about 85% sand), a particulate structure, a low water and mineral retention capacity, a phosphorus deficiency due to acidity that favors its blocking and cannot sustainably support agricultural production (Koy, 2010, Nsombo, 2016).

These soils are subject to strong mineralization of their organic matter and increased leaching of mineral elements caused by high temperatures and intense rains (Serpantié, 2009); thus leading to a drastic reduction in agricultural production (Dabin, 1984; Ruganzu, 2009)

On the agricultural level, the consequences are very low yields for the main food crops (Carsky et al., 2005). Despite the use of mineral fertilizers, the yield of the main crops decreases significantly after one cropping season due to the leaching of mineral elements (Egesi et al., 2007). To boost agricultural production in the DRC, it is necessary to improve the intrinsic fertility of its soils in order to correct their low productivity.

In response to the problem of the low fertility of these acid soils, their development requires organic or calcareous amendments to improve their physical-chemical properties and make the use of mineral fertilizers more profitable (Muna-Mucheru, 2007; Uyo et al., 2009). This will remove some of the constraints that hinder the increase of agricultural production and the production of food products for a rapidly growing population.

In DRC farming conditions, access to imported conventional fertilizers is not always easy due to their cost and even their availability. In addition, their use and dosage are not always well controlled. Thus, the use of local resources such as available plant species rich in certain minerals is necessary. (Bolakonga et al, 2007).

Concerning sandy and acidic soils, lime allows maintaining or raising the pH to the desired optimal limits; hence its interest as an amendment in the rhizosphere (Yalombe et al, 2017). It positively modifies soil chemical reactions by replacing H^+ and Al^{3+} ions in the absorbing complex with exchangeable basic ions Ca^{2+} and Mg^{2+}. This leads to the neutralization of the absorbent complex which was acidic.

The present study aims at improving the productivity of sandy and acidic soils of Kinshasa, by using agricultural lime and castor leaves as an alternative in the sustainable management of soil fertility.

Methodology

This study was conducted at two sites within the University of Kinshasa. The experiments had a completely randomized design that included a total of five treatments and four replications. At the sites, each treatment had eight polyethylene bags and a total of 160 bags were used.

Conduct of the trial

A mixture of soil from the sites taken from the first 20 cm was used, this was the topsoil. It was mixed in order to allow a good homogenization before filling the polyethylene bags.

Lime was used throughout, at a rate of 20 g per polyethylene bag; it was buried in the soil 14 days before sowing. This was the control treatment.

Castor leaves were used in a fresh state. The quantity per bag was respectively 200g, 300g, 400g and 500g for the different treatments, except for the control treatment which contained only lime. The leaves were cut and buried 14 days before sowing, which was done with three seeds per bag.

Soil analysis

The soils parameters considered were: pH, CEC and organic carbon. For the determination of the targeted parameters, the soil samples were taken 3 times: before the 1st sowing, and before the 1st harvest, et after second harvest.

Samples of each treatment were collected and air-dried in the lab before their analyses of the following parameters: pH, CEC, organic matter and available phosphorus. Soil pH was measured in a 1:2.5 ratio (weight/volume). CEC was determined by a paste extract with an ammonium acetate solution at pH 7 and a soil-solution ratio of 1:4.

Soil organic carbon was determined by the Walkley and Black method (Pauwels et al., 1992) that consists of oxidation of organic carbon by Potassium dichromate ($K2Cr2O7$) in a strong acid solution ($H2SO4$). The soil organic matter content was calculated by multiplying organic carbon content by a factor of 1,724 (the conversion factor is based on the fact that organic matter has on average 58% of organic carbon (Van Ranst et al., 1999).

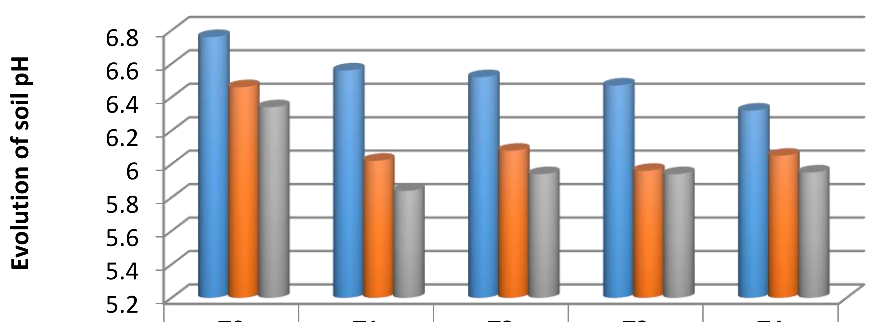
Statistical Analyses

All data collected from each treatment were entered and statistically analyzed by analysis of variance using Statistix 10.0 software. Comparison of the different means was done using the Least Significant Difference (LSD) test at the 5% probability level.

Résultats

Physico-chemical properties of soil

Soil acidity: Figure 1 presents the results of soil the pH after two growing seasons after application of different treatments.

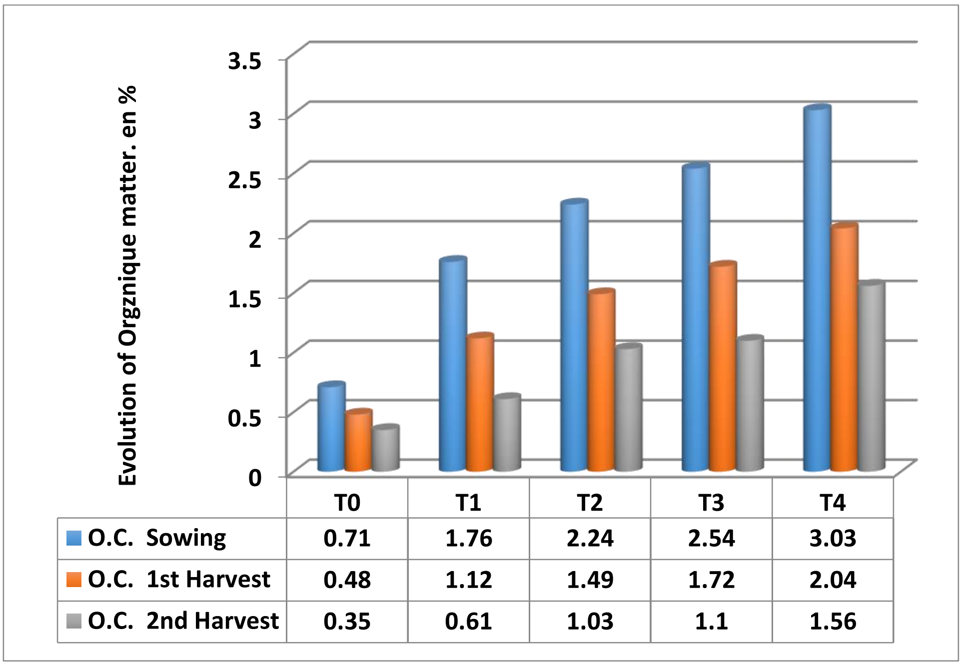


	T0	T1	T2	T3	T4
Sowing	6.76	6.56	6.52	6.47	6.32
1st Harvest	6.46	6.02	6.08	5.96	6.05
2nd Harvest	6.34	5.84	5.94	5.94	5.95

Legend: T0: Control soil with 20 g of lime, T1: Soil with 20 g of lime + 200 g of castor leaves, T2: Soil with 20 g of lime + 300 g of castor leaves, T3: Soil with 20 g of lime + 400 g of castor leaves, T4: Soil with 20 g of lime + 500 g castor leaves.

In view of the results of figutr 1, it results that after burial of the amendments the pH of the control which was of 5.2 went up of more than one and a half unit (1.5), tending towards neutrality. This was the case for all treatments. An average decrease of half a pH unit after each harvest.

Figure 2 presents the evolution of soil organic matter during the two growing seasons.



Legend: T0: Control soil with 20 g of lime, T1: Soil with 20 g of lime + 200 g of castor leaves, T2: Soil with 20 g of lime + 300 g of castor leaves, T3: Soil with 20 g of lime + 400 g of castor leaves, T4: Soil with 20 g of lime + 500 g castor leaves.

The organic matter content is high in the treatments having received castor leaves according to the quantities of amendment used. The organic matter content is low for the control because no plant biomass was added for this treatment.

After the first cropping season, the decrease in organic matter content is less noticeable in treatments T0 and T4. These treatments showed a decrease of about 30% in organic matter content recorded before the first cropping season. Treatments T1, T2 and T3 induced a decrease of about 50% of their organic matter content before the first cropping season.

After the second cropping season, there was a decrease in organic matter content in all treatments compared to the results in Table 4. The control had a very low organic matter content with a value below 0.7%. Treatment T4 had the highest organic matter content of the other treatments at 2.68%.

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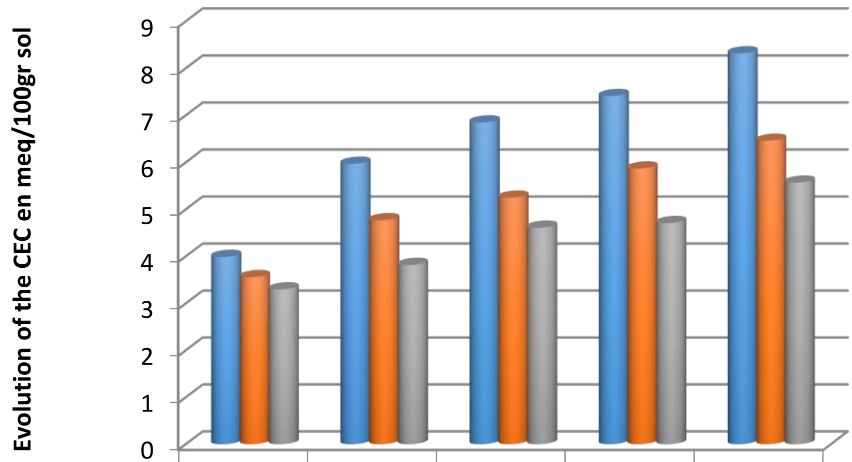
Figure 3 presents results of values measured for CEC of soils during the two growing seasons.



	T0	T1	T2	T3	T4
C.E.C. sowing	3.99	5.97	6.85	7.41	8.32
C.E.C. 1st arvest	3.56	4.77	5.25	5.87	6.46
C.E.C. 2nd arvest	3.3	3.82	4.61	4.71	5.57

The recorded CEC values increased by an average of one unit with an increase in castor oil doses of 100 g per bag, from 5.97 meq/100 g soil for the 200 g dose to 8.32 meq/100 g soil for the 500 g dose; the control did not receive the organic matter. The value of the control is less than 4 meq/100g soil.

CEC decreased in all treatments. The decrease in CEC was less remarkable in treatments T1, T3 and T4. These treatments induced a decrease of about 25% of their CEC recorded before the first cropping season with values between 4 and 7 meq/100 g soil. The T2 treatment showed a decrease close to 50% of the CEC before the first cropping season. The control (T0) showed a decrease of less than 10% in CEC before the first cropping season.

From this table 3, it appears that after the second cropping season, the decrease in CEC in all treatments. Treatments T0, T1, T2 and T3 showed a CEC value lower than 5 meq/100g soil compared to the results recorded before the first cropping season. Only treatment T4 had a CEC value higher than 5 meq/100g soil in the second cropping season.

Table 1: Effects of different treatments on the production of Okra during two growing seasons.

Treatments	Average weight of fruits (gr)	
	1st season	2nd season
T0	42,1b	13,6c
T1	53,1b	22,9bc
T2	115,9a	33,5ab
T3	116,1a	36,6a
T4	129,4a	41,1a
Average	91,32	29,54

The above table shows significant differences between treatments according to the LSD test. Treatments T2, T3 and T4 yielded more than the control (T0) and T1. Their values are significantly higher than the control (T0) and T1. Numerically, treatment T4 has a higher average fruit weight than all other treatments (129.4 g). The control has a low average weight about one third of treatments T2, T3 and T4.

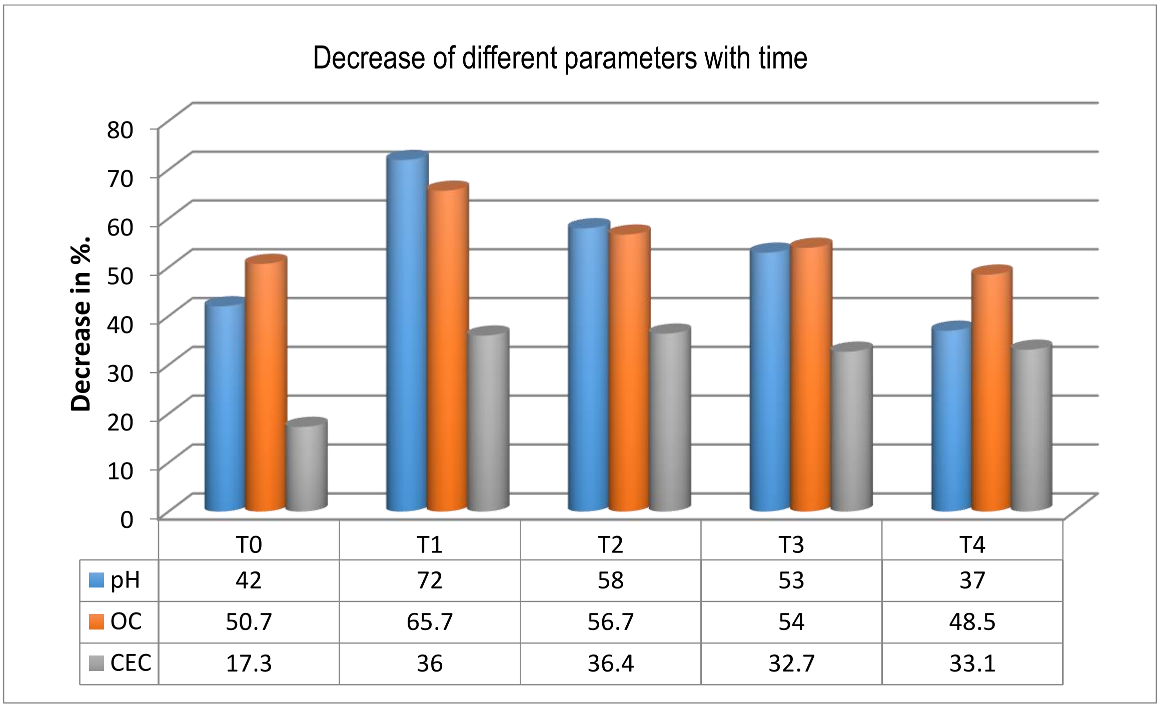
In the second season, it was found that treatments T2, T3 and T4 yielded more than the control (T0) and treatment T1. Their values are significantly higher than the control (T0) and T1. Numerically, treatment T4 had a higher average fruit weight than all other treatments. The control showed a low average weight (13.6 gr), which is one third of the T4 treatment. With time, the average number of fruits per plant as well as the weight decreased respectively by 42% and 66%, regardless of the treatment considered.

Discussions

Regarding the production parameters in the two cropping seasons, the treatments (T2, T3 and T4) recorded satisfactory results in terms of fruit weight. This is justified by the contribution of organic matter in the soil, which played an important role by providing major nutrients, which induced the increase in production (Mulaji, 2011; Ntuka et al. 2020).

The drop in yield was observed in the second cropping season, the observed yield is one-third of the yield in the first cropping season for all treatments. This can be justified by the fact that the organic matter in the soil becomes mineralized over time and no longer releases enough useful nutrients for the plant and for crop production.

As for the edaphic parameters, it is shown that the control gave a higher pH than the different combinations, i.e. 6.76. These values are within the range of average values allowing the availability and assimilation of most mineral elements in the soil. Also, lime brings the pH towards neutrality thanks to the replacement of H+ and Al3+ ions on the absorbing complex by exchangeable basic ions Ca2+, Mg2+ favorable to the assimilation of mineral elements. The results corroborate those found by Yalombe et al (2017) who had found a pH of 6.77 for lime and 6.1 for the lime and Tithitonia diversifolia combination.



In the soil that received the green organic matter as in the treatments with different combinations of lime and castor leaves, the soil acidity tends to increase due to the low release of organic acids (Duchaufour, 1995). This decrease may be due to the different amounts of organic matter releasing organic acids at different proportions and an influence on soil CEC and phosphorus availability (Christophe, 2014).

According to Pernes-Debuyser and Tessier (2002), organic or mineral amendments tend to acidify the soil, depending on their compositions if they provide little basic elements that can meet the needs of the crop in place. The results found show that by combining lime with organic matter, the CEC increases with different amounts of castor leaves.

The results confirm those found by Thuriès et al (2000) who indicated that organic fertilization leads to an increase in the cation exchange capacity (case of sandy soils). The contribution of organic matter improves the cationic exchange capacity by releasing organic compounds that generate electronegativity and allow to fix cations. This CEC is continuously decreasing according to the organic matter content during the two cropping seasons, this is explained by the decrease of the organic carbon of the soil by mineralization and consequently a lack of electronegative sites where the cations are fixed (Koull, 2007).

Conclusion and recommendation

With regard to the results obtained during the two cropping seasons, it is clear that the combined application of lime and castor leaves increased the cation exchange capacity of the experimental site from 1.71 meq/100g of soil to a value greater than 5 meq/100g of soil compared to the control (lime) with a value of less than 4 meq/100g of soil in the first cropping season.

This cation exchange capacity decreases in the second cropping season due to the decrease in organic matter which becomes mineralized. Only the combination of lime and 500 g of castor leaves gave a value higher than 5 meq/100 g of soil. The combined application of lime and castor leaves increased the organic matter content of the initial soil from 0.84% to a value above 3% compared to the control in the first cropping season and decreased in the second season to a value below 3%. The use of lime improved the pH of the experimental site from 5.6 to 6.7. The combination of lime and castor leaves also helped to maintain the soil pH at values above 6.

The results obtained showed that the combined application of lime and castor leaves had a positive influence on the growth parameters compared to the control (lime) in the first growing season. And, in the second cropping season, a decrease in growth for all treatments. Based on the production parameters (number of fruits and weight of fruits), it was demonstrated that the addition of green biomass of castor leaves combined with lime gave a good yield in the first cropping season compared to the control. The organic amendment is crucial on the production due to their high CEC which allows to retain the mineral elements of the soil and to make them available for the plants.

Organic matter is of fundamental importance for the sustainability of soil fertility and therefore for sustainable agricultural production, due to its physical, chemical and biological effects. In the second cropping season, a significant decrease in terms of production for all treatments. The observed decrease is one third of the first production in terms of average fruit weight. This study shows that lime cannot be used alone for production. Apart from its role in correcting pH and increasing cation exchange capacity, it does not provide primary mineral elements such as N, P, K except for calcium in the soil which the plant does not use in large quantities. The results of our investigations showed that the residual effects are not evident on the growth and yield of okra.

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