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Evaluation of the Growth and the Nutritional Status of the Leaves and Roots of Moringa oleifera under the Influence of Organomineral Amendments in Humid Tropical Region

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Résumé :

Evaluation de la croissance et de l'état nutritionnel des feuilles et des racines de *Moringa Oleifera* L. en fonction d'amendements organo-minéraux en région tropicale humide

Cette étude a été initiée dans le but d'évaluer l'influence des engrais organo-minéraux sur la croissance et la composition minérale des organes de *Moringa oleifera*. Trois doses de fumier de vache, trois doses d'engrais minéral et deux doses combinant l'engrais minéral au fumier de vache ont été comparées. Au cours des deux premières années de l'expérimentation, des échantillons de feuilles et de racines de *M. oleifera* ont été analysés au laboratoire. Les résultats ont révélé que les engrais minéraux ont amélioré les propriétés chimiques du sol, à l'exception du pH. Il ressort après analyse des paramètres végétatifs que le meilleur développement est obtenu avec la dose 125 kg d'engrais minéral par hectare. Cependant, la composition minérale de *Moringa oleifera* a été améliorée par l'application de la matière organique comparativement aux engrais minéraux. Lors de la deuxième année de récolte les résultats ont montré que les jeunes feuilles de Moringa étaient plus riches en humidité et en cendres tandis que les feuilles matures présentaient des teneurs élevées en lipide, cellulose et protéines. Dans un contexte de malnutrition, l'espèce *Moringa oleifera* L. constituerait une solution durable quand celle-ci est cultivée avec amendement organique

Abstract :

This study aimed to evaluate the influence of organomineral fertilizer on the growth and mineral composition of Moringa oleifera organs. The experiment included three doses of cow dung, three doses of mineral fertilizers and two doses combining mineral fertilizers and cow dung. Soil samples and samples of M. oleifera organs were analyzed. Results revealed the contribution of fertilizer to improve soil chemical properties, except pH. The best vegetative development was obtained with the dose of 125 kg of mineral fertilizers per hectare. However, the mineral composition of *Moringa oleifera* has been improved by the application of organic matter compared to mineral fertilizers. In the second year of harvest, the results showed that the young leaves of Moringa are rich in moisture and ash, whereas mature leaf, have high levels of lipid, cellulose and proteins compared to young leaves. In the context of poor nutrition, *Moringa oleifera* L. is a sustainable solution when grown organically.

Keywords : Moringa oleifera, cow dung, mineral fertilizers, organs, tropical humid region, Democratic Republic of the Congo

Introduction

The annual global statistics estimate to seven million the number of people starving. The majority would be reached of chronic bad nutrition (16). Between 2012 and 2014 nearly 805 million people lived in chronic under nutrition according to the United Nations Food and Agriculture Organization (15). The main reasons were the unavailability of vegetables essential to good health (23). It annually awards the death of 2.7 million people with insufficient consumption of fruits and vegetables. It is ranking among the top 10 risk factors for mortality (13). The DR Congo classified among developing countries, would contain more than 6.4 million people, where 10% of its rural population living in a situation of acute food crisis and lack of means of subsistence (39). The major constraints of not eating vegetables and fruits are the price increase during deficiency season combined with low population income. To fill food need, many researchers propose the use of undemanding plants, but with high nutritional value (23, 24). Indeed, the Moringa has been identified as a miracle plant species that can be used as a highly nutritious vegetable, medicine etc. (43). Moreover this species is used in water treatment by replacement of iron and aluminum salts (31). Moringa is also involved in water pollutant immobilization in areas contaminated by heavy metals or other products such as hydrocarbons, which proves the virtue of this species (25, 4). Due to their high content of protein, Moringa seeds are involved in the fight against childhood protein deficiency observed in rural areas due to poverty (17). The advantages of this shrub related to its high content of essential nutrients, its drought resistance, contains low noxious compounds such as tannins and phytates (32). Moreover, Moringa is known for its high content of digestible protein, iron, calcium, vitamin C and carotenoids (36). The leaves also contain appreciable amounts of magnesium, selenium and zinc (18).

Current study is part of the research of techniques that increase the nutritional value of Moringa in order to effectively reduce the number of people suffering from malnutrition on a global scale (50). Mineral and organic fertilizers are known for their role in increasing the market value (quality and quantity) of crops in proportion to the dose applied (33). To our knowledge, no study has been able to assess the nutritional value of moringa's organs based on fertilizer inputs. The aim of his research is to evaluate the nutritional value of Moringa different organs depending on kinds and doses of fertilizers. The hypothesis emitted in this research are (i) Fertilizers according to their kinds and doses would influence the nutritional value of Moringa, (ii) all organs do not have the same nutritional value depending on kinds and doses of applied fertilizers.

Material and methods

Description of the study site

Called copper capital, Lubumbashi is the capital of The Upper-Katanga, province located at 11°39' South latitude and 27 ° 28' East longitude in DR Congo. It is currently composed of 42 districts spread over 7 municipalities: Lubumbashi, Kenya, Kampemba, Katuba, Kamalondo, Ruashi and Annexe. This region is characterized by a climate of Cw6 type according to Koppen classification (30). It includes a normal growth period of crops (182 days: from the second half of October to mid-April) and a wet period (about 150 days: the first half of November until the first decade of April) (24). The annual rainfall is 1270 mm with extreme values of 717 and 1770 mm. The annual average temperature is about 20°C (30). The primary vegetation of the city of Lubumbashi is Miombo woodland types. However, due to human activities, this woodland is replaced by secondary vegetation consists of savannah in the suburban area.

Description of the test

Mature seeds of Moringa oleifera, harvested from trees in the Mulungwisha Methodist University were used as biological material in this study. Well known for their high germination rate, the seeds were stored outdoors for better preservation of germination. The mineral NPK fertilizer (10-20-10), the most marketed and used by local farmers, was obtained in an agricultural hardware store. The cow dung came from Mimbulu farm. Doses of NPK were 125kg, 167 kg and 208 kg; while a mixture of fertilizer to the cow dung (OM) included 417 kg OM + 42kg NPK; 833 kg OM + 83 kg NPK; and finally three doses of cow dung respectively contained 1250 kg, 1667kg and 2083 kg per hectare. In this experiment, the dose of 1250 kg OM was considered as control treatment because of its use by several researchers. A randomized complete block design with four replicates was established with eight treatments. The experimental unit is a plot of 4.8 m² (2x2.4 m) spaced from one another of one meter. Before sowing, seeding was performed after sorting uniform size and without distortion, the latter were put in a warm (50°C) for 12 hours as recommended by (38) for lifting seedcoat dormancy. After all these operations, seeds were sown at a depth of 1 cm and spacing of 40 cm in the line and between, making a total of 62500 seedlings per hectare. As far as the appearance of weeds and due to the heavy rain of the tropics, weeding and hoeing intervened periodically, and mulch was placed for water loss and evapotranspiration reduction. Three months after sowing, the plants were pruned to encourage branching, while newly emerging leaves, mature leaves and roots were harvested. The leaves and roots were dried and powdered for subsequent analysis in the laboratory of CRAA (Centre de Recherche Agro-Alimentaire) through the spectrometer.

The composite soil samples were taken from 0-15cm before and after testing for chemical analysis.

During experimentation, the different functional features characteristic of the species for different treatments were observed:

- Lifting rate at 17th days after planting (%): It was determined by the ratio of seedlings per plot * 100/ number of sown seeds;
- The evolution of the survival rate (%): the ratio of surviving plants / number of lifting plants;
- The evolution of plant height to 32, 47, 62, 77, 92, 107 and 122 days after sowing (cm): it corresponds to the length of the main stem (of the neck at the top of the plant) the using a ruler;
- The evolution of the collar diameter 62, 77, 92, 107 and 122 days after sowing was determined using a caliper or compass forest (mm);
- Changes in the number of leaves of the plant 32, 47, 62, 77, 92, 107 and 122 days after sowing: it is determined by counting all the leaves from seedling emergence until harvest.

Chemical analyzes of the laboratory have carried on:

- The pH of water before and after testing (ground);
- The content of major elements (N, P, K, S, Ca) and trace elements (Cu, Si, Al, Cl, Fe, Mn) and C. It should be noted that these elements were analyzed in composite samples.

In the second year of the trial the protein content by the Kjeldahl method, the cellulose by the Weender method, the moisture content, the ash and the fat were determined. Statistical analysis was carried out using the R 2.14.1 software after data harvest, the aim being that of determining the differences between the average and the 0.05% was retained in this study.

Results

Influence of fertilizer inputs on vegetative parameters of Moringa

Emergence and survival rates

After analysis with the software at the 0.05 level, it was observed that there existed no significant difference between the lifting of seeds planted according to types and doses of fertilizers. The table below shows the averages for each treatment and the P value. So after monitoring the mortality of plants during the experiment, it was concluded through statistical analysis that there was no significant difference on the plants that survived had ways to treatment (Table 1).

Table 1: Effect of organomineral fertilizers on emergence and survival rates of Moringa

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	P
Emergence rate (%)	79±20.9	69±17.3	85±10.5	79±10.7	90±8.2	70±17.1	79±14.6	69±22	0.27
Survival rate (%)	78±20.8	71± 4.8	79±19.5	95 ± 6.4	69±11.3	88±15	93±9.6	85±23.9	0.61

Caption: T1: 1250 kg OM; T2: 1667 kg OM; T3: 2083 kg OM; T4: 417k g OM + 42 kg NPK; T5: 833 kg OM + 83 kg NPK; T6: 125 kg NPK; T7:167 kg NPK; T8: 208 kg NPK per hectare.

Collar diameter, plant height and number of leaves

The average levied on various treatments have proven that there was no significant difference between them after analysis of variance at 92th day after sowing. At this date significant differences were observed between treatments, with a larger diameter for treatment with 83 kg of NPK, while treatment with 1250 kg OM had low collar diameter as shown in the table below. While the plant size parameter has shown indifference to fertilizer inputs until the 47th day after sowing, however a significant influence was observed from the 62th day between treatments. During the experiment the difference has been proved significant (<0.01) between treatments. Whereas, over 107th day after planting until the harvest time, the tendency appeared similar between the treatments. The number of leaves in the experiment at 107th days remained with no significant difference, so that from that date the plants that received 125kg of NPK carried a number of leaves superior to other treatments, whereas treatment with 208kg of NPK showed a low number of leaves (Table 2).

Table 2: Effect of organic and mineral fertilization on collar diameter (mm), plant height (cm) and number of leaves

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	P
CD62	6.2± 0.49	7.5± 1.84	7.9± 1.19	7.9± 1.5	8.4± 1.92	9.1± 3.19	8 ± 0.8	7.8± 1.01	0.11
CD77	8.1± 1.27	9.4 ± 2.2	10.2± 1.97	10.6± 2.13	11± 3.13	11.8± 4.12	10.6± 0.98	10± 3.15	0.0998
CD92	11.5±2.20b	12.6± 2ab	13.1± 2.24ab	14± 1.78ab	14.4± 2.28ab	16.5± 4.75a	15± 2.35ab	14.3± 3.67ab	0.04
CD107	12.4± 3.39b	14.9± 2.45ab	15.3± 2.83ab	15.3± 2.62ab	16.2± 3.03ab	18.3± 3.83a	16.8± 3.42ab	16.5± 4.59ab	0022
CD122	13.7± 3.54b	15± 4.27ab	17.2± 3.44ab	17.3± 3.5ab	17.7± 3.71ab	19.2± 4.79a	17.9± 3.38ab	17.5± 5.28ab	0029
HP62	12.4± 1.26b	16.4± 3.75ab	18.6± 2.66ab	18± 3.58ab	17.8± 3.28ab	22.9± 9.45a	17.1± 1.48ab	17± 5.67ab	0.0187
HP77	19.2± 2.39	24.9± 6.22	27.8 ± 4.4	29.3± 7.5	27.7± 9.98	37± 17.46	28.3± 2.49	26.5± 9.273	0.063
HP92	17.4± 5.66b	19.6± 7.45b	26.5± 6.61ab	25.8± 6.4ab	28.9± 12.14ab	36.9± 15.55a	25.8± 4.79ab	29.4± 13.54ab	0.009
HP107	29.7± 8.27	42.3± 18	46.3± 7	47.9± 13.3	44± 16.78	59.2± 25	45.5± 11.99	49.4± 22.58	0.3
HP122	36.8± 12.2	50.5± 23.2	56.4± 13.7	54.5± 12.8	51.1± 16.7	68.6± 26.3	49.5± 10.2	54.4± 20.3	0.0588
NF62	11.4 ± 1.7	12.2± 1.5	13.2 ± 1.8	12.4 ± 2	13.4 ± 2.1	14.1± 2.7	12.1± 1.7	10.8 ± 1.8	0.19
NF77	14.5 ± 1.9	14.7± 1.5	15.9 ± 2	15.6± 1.8	16.7 ± 2.6	16.4± 3.3	16.1± 1.5	12.5 ± 2	0.1
NF92	14.4 ± 2.9	11.1 ± 1.6	14.4 ± 1.4	15.2± 2.8	15.6 ± 1.1	15.7± 4.6	12.5± 3.2	10.7 ± 4.4	0.13
NF107	22.4± 4.7ab	25.3± 2.86ab	26.5± 5.52ab	22.6± 3.83ab	25.4± 3.67ab	29.6± 7.29a	23.1± 5.58ab	18.1± 7.87b	0.0093

NF122	17.5 ± 6.3	21.2± 8.4	22.9 ± 8.9	20.3± 5.4	21.8 ± 8.4	24.3± 6.7	19.3 ± 3.1	17.4± 10.3	0.29

Caption: (T1: 1250 kg OM; T2: 1667 kg OM; T3: 2083 kg OM; T4: 417 kg OM + 42 kg NPK; T5: 833 kg OM + 83 kg NPK; T6: 125 kg NPK; T7:167 kg NPK; T8: 208 kg NPK) per hectare. The different letters next to the averages indicate a significant difference after the Tukey test at the 5% probability threshold. OM: organic matter CD: collar diameter; HP: height of plants; NF: number of leaves; 62, 77, 92, 107 and 122nd day of observation.

Influence of fertilizer inputs on the chemical properties of soil and vegetative organs

Effects of the type of fertilizer on the improve of soil chemical properties

The table 3 illustrates the various chemical parameters considered in this study, after preliminary laboratory analysis of soil samples taken before and after testing.

Table 3: Effect of type of fertilizer on soil chemical properties

Fertilizers	pH	N (g/kg)	P (g/kg)	K (g/Kg)	OM (%)
Unfertilized soil	5.76	0.00335	0.156	-	1.5
Organic matter Quantity?	5.38	0.00166	0.25	10.6	5.4
NPK	5.14	0.00162	0.38	11,16	5.2
Combination Organic matter +NPK	5.51	0.00213	3.21	23/37	8.8

Effect of fertilizer inputs on the chemical composition of vegetative organs of Moringa

Examination of table 4 shows that nitrogen (44.38 g/kg) and potassium (35.2025 g/kg) are the most abundant mineral elements in young leaves. However, silicon (51.4175 g/kg) and nitrogen (43.120g/kg) have high levels compared to other mineral elements. Whereas iron (252.0325g/kg) and calcium (199.53 g/kg) are the most dominate in the roots. Copper and Manganese are the only mineral elements that are the most enriched in young leaves and roots respectively (Table 4).

Table 4: Chemical composition of the organs of Moringa oleifera L (on fresh matter)

Elements	young leaves (g/kg)	Mature leaves (g/kg)	Roots (g/Kg)
N	44.38	43.12	28.01
P	3.15	1.71	49.94
K	35.20	41.45	36.75
Ca	11.94	25.09	199.53
Fe	2.03	5.69	252.03
Mn	0.45	0.45	143.8
S	3.73	1.93	2.35
C	20.55	25.96	39.68
Cl	15.08	17.70	0.64
Cu	0.10	0.18	0.64
Si	33.11	51.42	31.50
Al	12.06	12.99	3.55

Content of major elements in young and mature leaves

The content of different major elements that have been measured in young and mature leaves according to the amendments are presented in table 5. It has been observed that the content of different elements in both leaf types is similar overall for different treatments.

Table 5 : Residual effect of amendments on content of major elements in young veined Moringa leaves according to treatments

Treatments		K	P	S	Na	Mg	Ca
young leaves (mg/kg) Fresh matter	T1	790.11	184.11	668.35	82.65	379.20	25.20
	T2	794.61	189.25	676.21	83.67	377.35	24.37
	T3	791.64	182.50	578.35	81.25	375.64	23.35
	T4	795.32	188.65	666.25	84.22	378.64	24.97
	T5	792.56	183.64	601.32	82.46	379.31	22.56
	T6	794.46	187.65	675.17	83.81	376.93	25.46
	T7	790.32	181.27	579.68	82.65	377.64	23.35
	T8	796.15	189.50	656.22	85.65	378.61	24.65
Mature leaves (mg/kg) Fresh matter	T1	798.21	187.65	642.32	83.91	377.35	22.35
	T2	791.36	183.54	602.32	82.15	373.13	25.15
	T3	794.32	188.65	685.22	84.66	375.33	24.64
	T4	792.37	183.22	589.33	82.94	374.49	23.66
	T5	795.37	185.55	645.31	84.99	377.25	22.95
	T6	792.13	180.18	595.00	81.18	376.21	23.90
	T7	794.69	187.80	632.22	83.97	378.45	25.17
	T8	791.80	181.25	612.33	82.44	374.27	24.81

Legend: T1: 1250 kg OM; T2: 1667 kg OM; T3: 2083 kg OM; T4: 417 kg OM + 42 kg NPK; T5: 833 kg OM + 83 kg NPK; T6: 125 kg NPK; T7:167 kg NPK; T8: 208 kg NPK) per hectare.

Micronutrient content in Moringa leaves according to treatments

Table 6 below shows the levels of micro-nutrients analyzed in young and leaf vegetation as a function of the residual amendments. On the other hand, it has been observed that the content of these elements in young and mature leaves does not show a significant variation for all treatments. However, it is noted that the Manganese followed by Iron is more pronounced compared to the other trace elements analyzed (Table 6).

Table 6 : Residual effect of amendments on micro-nutrient content in young and mature Moringa leaves as a function of treatment (on fresh matter)

	Treatment	Cu	Fe	Mn	Zn	Se	Mo
young leaves (mg./kg)	T1	0.98	19.79	274.31	2.19	0.05	0.29
	T2	1.00	19.92	276.19	2.55	0.06	0.30
	T3	0.97	19.90	271.25	2.26	0.05	0.23
	T4	0.99	19.68	277.46	2.46	0.06	0.30
	T5	0.90	19.60	273.69	2.32	0.05	0.20
	T6	0.98	19.56	278.47	2.98	0.07	0.32
	T7	0.88	19.98	273.64	2.33	0.05	0.20
	T8	0.99	19.88	275.61	2.76	0.07	0.33
Mature leaves (mg/kg)	T1	0.95	19.79	276.22	2.65	0.06	0.32
	T2	0.83	19.94	272.42	2.32	0.02	0.19
	T3	0.98	19.68	276.12	2.55	0.05	0.29
	T4	0.90	19.98	272.46	2.21	0.03	0.20
	T5	0.90	19.68	277.55	2.42	0.06	0.32
	T6	0.83	19.13	273.02	2.10	0.01	0.28
	T7	0.90	19.98	276.81	2.65	0.04	0.33
	T8	0.90	19.99	274.65	2.31	0.02	0.20

Legend: T1: 1250 kg OM; T2: 1667 kg OM; T3: 2083 kg OM; T4: 417 kg OM + 42 kg NPK; T5: 833 kg OM + 83 kg NPK; T6: 125 kg NPK; T7:167 kg NPK; T8: 208 kg NPK) per hectare.

Organic composed (nutritive) content in Moringa according to treatments

The results on the organic content in the leaves (Table 7) show that high moisture and ash contents are obtained in young leaves. On the other hand the mature leaves of Moringa present high levels of lipid, cellulose and proteins compared to young leaves. As far as total sugars are concerned, the result of the laboratory shows the absence of this organic compound in the leaves of the Moringa (7).

Table 7 : Residual Effect of Amendments on Organic (Nutrient) Composition in Young and mature Moringa leaves as a function of treatment (on fresh matter)

	Treatment	Humidity	Cinder	Lipid	Total sugar	Protein	Cellulose
young leaves (mg/kg)	T1	6.73	13.13	6.72	0	24.35	3.97
	T2	6.9	12.11	6.88	0	23.31	3.8
	T3	6.48	13.15	6.84	0	24.3	3.72
	T4	6.17	13.13	6.84	0	25.21	3.78
	T5	6.05	12.59	6.81	0	25.21	3.99
	T6	6.05	12.9	6.81	0	25.21	3.79
	T7	6.59	12.9	6.71	0	25.85	3.79
	T8	6.47	12.66	6.71	0	25.85	3.8
Mature leaves (mg/kg)	T1	4.5	11.39	7.27	0	25.69	4.02
	T2	4.63	10.68	7.22	0	25.59	4.21
	T3	4.12	11.36	7.26	0	26.6	4
	T4	4.11	11.55	7.26	0	26.51	4.3
	T5	4.11	11.43	8.01	0	26.04	4.01
	T6	3.58	10.69	8.01	0	26.04	4
	T7	4.42	11.31	7.26	0	26.18	4.06
	T8	4.59	11.27	7.29	0	26.18	4.02

Legend: T1: 1250 kg OM; T2: 1667 kg OM; T3: 2083 kg OM; T4: 417 kg OM + 42 kg NPK; T5: 833 kg OM + 83 kg NPK; T6: 125 kg NPK; T7:167 kg NPK; T8: 208 kg NPK) per hectare.

Discussion

The similar effect of used fertilizers on emergence rates as observed in this study corroborates the study conducted by Asaolu *et al.* (5). This studies assumes that seed emergence is more influenced by its maturity and method of conservation than by the types of applied fertilizers. Moreover, Useni *et al.* (47) stated that seed germination of seeds depends more on the nutritional reserves contained in the cotyledons until the appearance of first leaves. At the stage of germination, nutrients are not available to the culture and therefore, plants installed on soil with fertilizers would behave in the same manner as those installed on unfertilized soils. In light of these studies and the results obtained in this research, it is possible to state that the lifting of seed placed underground would be based on the intrinsic nutrient supply, state of maturity and the soil conditions. However, Asaolu *et al.* (5) obtained significant difference on the emergence rate based on seed treatment before sowing method. This same study found that scarification of Moringa seeds in hot water at 60°C for one hour favored the rapid emergence. The germination process could be initiated by the favorable climatic conditions (temperature) at planting. Indeed, at planting if the temperature is optimal according to culture exigency, this would imply a perfect emergence. In tits study, Nyembo *et al.* (34) obtained a low emergence rate after the non-respect of the agricultural calendar (sowing date). They found that late sowing generally coincides with the period of greatest proliferation of rodents and other diseases including damping off. Hence it then proves important as the planting date is each time consideration for a perfect lift. However, that early sowing made in wet conditions, are at risk of significant slowdown (12). Although having been some mortality of seedlings on some plots, the ad hoc test found no significant difference between the various inputs of fertilizers. Abou-Elezz *et al.* (1) demonstrated that the survival although dependent on external factors such as fertilization, would be more influenced by climatic conditions. Thus these factors being equal favor more than any other factor the seedling survival similarity. It was then that the lower mortality observed during the experiment was due to the rotting roots that causes a sudden drying of leaves followed by widespread plant death. For Palada and Chang (37) this root putrefaction was induced by Diplodia attacks. Collar diameter proved similarly after analysis of variance between the different treatments until the 90th day after sowing. Plots with 188kg of mineral fertilizers showed a high value of diameter, whereas with the addition of organic amendments, it was obtained the low value of the diameter. It is noted that the results of this study are not in accordance to those of Pamo *et al.* (38) who obtained the best result of the diameter with organic fertilizer applications. This could suggest that the influence of organic amendments depends on the state of decomposition of these before intake, and a material with advanced mineralization gives better result than that still intact. In the same context (9) revealed the availability of mineral elements was based on the decomposition (mineralization) of organic amendments. Indeed, in the presence of organic amendments to an initial phase of decomposition, mineral fertilizers work better because having a fast availability of minerals (2).

As for the plant height, it was observed a significant difference between treatments at 62th and 92th day after sowing ($p<0.05$). Plots with 125 kg of mineral fertilizers showed a higher height than those with other doses of mineral fertilizers and other amendments. This observation is aligned in the same lines as those of Aïssi *et al.* (2) showing that the growth of a plant is based on the availability of mineral elements. Thus Annongu *et al.* (3) who correlated positively the growth of plant organs and availability of major mineral elements. Knowing that mineral fertilizers have the ability to release soon the major elements in the ground, this phenomenon would favor a proportionate growth of crops. A significant difference was also obtained between the numbers of leaves as fertilizer inputs. Indeed, the plots treated with 125 g of NPK as for other vegetative parameters have shown better than others as regards the number of leaves. This result was obtained by Mpundu *et al.* (30) in an essay on the application of increasing doses of fertilizers. Although organic fertilization has a significant effect on the growth of plants, the choice of the decomposition state remains the key to a better use of elements that they contain. To this end some researchers propose incubation of organic amendments before use for better release of mineral elements.

Soil pH (water) decrease taken at the end of the experiment was detected after laboratory analysis. (22) in a study on the influence of organomineral fertilizers have observed the same effects. This fact could be simply explained by the fact that mineral fertilizers are acidifiers, while organic amendments in turn contain certain organic acids, which causes a release of soil acidification (46). On the other hand, the rhizosphere is the proliferation zone of roots, this decline was due to the production of H + ions from the reaction between CO2 from land-based roots and faun respiration and decomposition of organic matter (35). This pH decrease sufficiently proofs the negative long-term influence of mineral fertilizer use policy on; tropical soil properties. The cultivation of land results in their short-term degradation. As soon clearing and litter disappearance, there was a rapid decline in soil organic matter and the beginning of chemical, biological and physical degradation of surface horizons. The fire suddenly mineralized bedding, releases CO2 and ashes that are blown by the wind or washed away during the first storms (40). It is to note that fertility management techniques practiced by farmers leading to a rapid depletion of soils (21). Indeed, soil cultivation results in an annual loss of 2 to 4% organic matter to reach the threshold of non-response to mineral fertilizers after 12 to 15 years of continuous culture the analysis of the nitrogen content before and after testing showed a negative trend in all plots given the type and dose of fertilizer. This result is not in accordance with those obtained by Kaho *et al.* (22) who revealed an improvement in soil nitrogen reserve after fertilization, shows that the level of fertilization is very low according to the need of culture. In Sub-Saharan Africa, most of fertilizers brought no benefits to the culture following the strong rainfall and temperature rise. The use of small amounts of fertilizer by farmers is due to the limited availability of chemical fertilizers due to a relatively high cost compared to farmers' incomes (23). These constraints cause a low intake of fertilizer to the ground that is not without negative consequences on the ground. Indeed, low fertilization leads to a depletion of soil mineral resources (24).

The phosphorus content and the organic matter of the soil was improved by the contribution of fertilizers, although the finding is different from results obtained by Useni *et al.* (48). Nevertheless, the situation of organic matter can be explained by the fact that mineral fertilizers could constitute a source of nutrition for telluric organisms capable of decomposing organic matter. These authors found that only the application of organic amendments has led to increased organic matter content of the soil while the application of mineral fertilizers given similar values to the control (without amendments). Although mineral fertilizers with zero organic matter content, the increase in plots fertilized with mineral fertilizers was due residual effects of weeds buried in the ground before and during the experiment. Due to the results obtained, the nitrogen and sulfur are high in young leaves than in other analyzed organs. However, in mature leaves, chlorine, potassium, silicon and manganese are more abundant compared to young leaves and roots. These results are different than those obtained by Aïssi *et al.* (2) who found that the most mobile elements such as chlorine, and potassium were more concentrated in the new leaves. However, for these authors, mature leaves are rich in more disabled elements (Mn and Si), as it was found in our study. This difference may be due to the species and the vegetative state of the plant (42). The high content of potassium and chlorine as mobile elements in mature leaves could be due to the fact that demand would be high in this period as described by Nyembo *et al.* (34). Similarly, the high sulfur content in new leaves explain the fact that some authors such as Havlin *et al.* (20) places this element in the category of medium mobility elements. Moreover, the protein content is high in young leaves (26) makes a connection between the latter and sulfur.

In young leaves, the variation of the content of mobile elements (nitrogen, chlorine, phosphorus, potassium) as a function of treatment was more pronounced for nitrogen and chlorine as compared to other elements. These results pair with those found by Azouz and Lassoud (6), these authors have shown that the variation in nitrogen content in sugar beet is a function of nitrogen fertilizer applied doses, of the organ and of the period of analysis. However, to our results a correlation is established between the vegetative parameters and the variation of the nitrogen content as a function of treatment. Indeed, treatment with 188 kg of mineral fertilizer induced at the same time a high nitrogen content in the new leaves and improved growth performance. This correlation is due to the fact that the treatments that cause a high biomass production induce an increase in the nitrogen content as described by Grechi (19). Similarly, Deblay (11) signal that mineral absorption has to adjust to the speed of development of new plant tissues, that is to say the dynamic absorption and metabolism of nitrogen.

According to the results obtained on the nutrient content in mature leaves according to amendments, changes in nitrogen, potassium, calcium, silicon and chlorine were most affected by the use of amendments than that of others elements. The contents of calcium, potassium and chlorine in mature leaves were most abundant under the effect of organic matter while the silicon in the presence of the NPK. These results are identical to those of Kaho *et al.* (22), according to these authors the absorption of nutrients by the plant is directly related to the concentration of these ions in the nutrient zone. However, the high levels of silicon in the mature leaves under the influence of NPK (T7 and T8) supports the work conducted by Bouzoubâa *et al.* (8). According to these authors, silicon regulates plant hydromineral nutrition and the fight against salinity.

In this study, the roots are richer in phosphorus, calcium, iron and copper as compared to other organs. These results are similar to those of *Vallès et al.* (49), for these authors there would be precipitation effects of phosphate, calcium, copper and iron ions in the form of insoluble salt crystals not only in the nutrient solution but also on the surface and in the roots.

Since for mineral fertilizer only nitrogen, phosphorus and potassium were applied to the soil, the results reveal that there has been a change in elements other than those mentioned above in the organs under the influence of NPK. Therefore, the elements have been obtained directly in the soil solution in function of the links it maintains with the nitrogen, phosphorus and potassium.

It is important to note that, for mineral fertilizers, except the nitrogen, phosphorus and potassium, the variation of contents of the other elements in the organs proves that such other elements have been obtained directly from the soil solution in function that maintains links with the nitrogen, phosphorus and potassium (29).

The highest carbon content was found in the roots compared to other organs. These results are in agreement with those of Tabourel-Tayot (45), these authors state that the roots are a sink element for carbon plant reserves.

However, the change in carbon levels depending amendments was acute for all organs. In general, treatments that have induced high and medium quantities of the number of leaves induced high levels of carbon in the leaves and roots, except for mineral amendments in the roots. Indeed, in the roots, T6 (125 kg NPK) and T7 (167 kg NPK), which had respectively high and medium quantities of the number of leaves, induced low levels of carbon. The levels of copper, aluminum, manganese and sulfur are remained stable in all organs despite the application of the amendments.

As the leaves are more consumed than roots, better amendment would maximize its abundance relative to its nutritious elements in both young and mature leaves. Due to soil chemical composition described above, mineral fertilizers it up must be excluded this category because, without addition of organic matter, plant draws some minerals in the soil solution and lead to the deterioration of the latter (48). According to the results described above, the organic matter is the perfect candidate because it maximizes the amount of elements in the leaves and maintains soil properties more or less stable.

The average levels of nitrogen in the new leaves are higher than those obtained by Millogo-koné *et al.* (28) for all leaves: 44.380 g/kg against 43.950 g/kg which may be due to the high rate of nitrogen. The high nitrogen content in new leaves over the mature leaves and roots can be used as important tip sources of protein and thus participated in the fight against malnutrition.

The average potassium content of the former sheets (41.446 g/kg) was greater than that obtained by Malo (27) (32.574 g/kg) to mature leaves of the variety PKM1. On the other hand, the calcium content of 25.09 g/g in mature leaves was higher than those of Malo (27) (10.654 g/kg). Phosphorus levels (1.706 g/kg for mature leaves), copper (0.18 g/kg for mature leaves), Iron (5.685 g/kg for mature leaves), manganese (0.450 g/kg for the mature leaves) were inferior to those obtained by Millogo-koné *et al.* (28) for all leaves. In fact, these authors obtained for a phosphorus content of 3800 mg/kg for copper 8.13 g/kg for the 677.77 Iron g/kg and manganese 62.93 g/kg. From the above, differences in nutrient content compared to those obtained by other authors cited above, may be due to environmental conditions of production areas, the maturity of the leaves, the methods of cultivation, harvesting season and genetic heritage of trees (41).

Compared with other foods, new leaves of Moringa are high in crude protein (27.75%) compared to concentrated yoghurts which according to FAO and OMS (14) is at least 5.6%. The new leaves protein levels are inferior to those obtained by Sodamade *et al.* (44): 39.13%. However, it is comparable to those of Vallès *et al.* (49) (27.51%). The potassium content obtained in our study (41.446 g/kg) was 8-10 times greater than that of bananas. The results show that by providing beneficial elements for the body, Moringa can be an important ally in the campaign against malnutrition. Indeed, potassium plays the role of hydro balance, functioning of the nervous and muscular systems, stomach and kidney reactions. Calcium is a component of the skeleton, and plays a role in muscle contraction. Phosphorus is a constituent of the skeleton, nucleic acids, membranes (phospholipids), energy (ATP), acid-base balance. Chlorine plays a role in the osmotic pressure regulation, participates in the formation of hydrochloric acid in the stomach. Iron is a component of hemoglobin and enzymes. Copper participates in bone mineralization, regulation of neurotransmitters, iron metabolism and enhancing immunity. Manganese is involved in carbohydrate and lipid metabolism as well as in the detoxification of free radicals. Silicon participates in the synthesis of collagen and proteoglycans, and in bone formation (10).

It has been revealed after laboratory analysis that the highest levels of organic (nutritive) composing in Moringa foliar organs is obtained in mature leaves may be due to the fact that mature leaves are rich in mobility elements and consequently it increases the concentration of the elements in the tissues. In comparison with other foods, the Moringa leaves have a high content of crude protein and the highest content was obtained by treatment 3 (26.6%). This content is much higher than that of concentrated yogurt, which according to (14) is at least 5.6%. Nevertheless, our values are lower than those of Sodamade *et al.* (44) found 39.13% of the same crop. Because the protein content is high in leaf watches, Lehner (26) makes a link between the latter and sulfur. Indeed, according to this author, sulfur is assimilated in the leaves (in the plastids) in the form of cysteine which can be incorporated into the proteins. According to Havlin *et al.* (20), Sulfur is one of the elements of mobility which could increase its concentration in tissues. Similarly, leaf watches have been shown to be rich in lipid, cellulose under the residual effect of amendments to the second year. And for the highest lipid (8.01 g/kg) observe with treatment T5: 833 kg OM + 83 kg NPK and T6 = 125 kg NPK which presented a similar value. This value is higher than that found by Saint sauveur and Broin (41) (7%).

Conclusion

This study aimed to analyze the influence of organomineral fertilizers on the growth and the chemical composition of edible organs of Moringa. To this end, a device in randomized complete block was installed in four replicates with eight treatments. It appears that the application of the amendments had no significant effect on emergence rate and survival rate. However, for all the vegetative parameters the dose of 125kg of mineral NPK fertilizer had a positive effect compared to other treatments. Thus, it was the best option for vegetative parameters. Concerning the chemical composition of the leaves and roots of Moringa, it was found a change in element content following the organ. Thus, the average contents of nitrogen and sulfur were raised in the new leaves. Therefore, the young shoots of Moringa leaves are a better source of protein compared to the mature leaves and the roots. Likewise, roots and young leaves gave higher levels of potassium, manganese, chlorine, silicon, aluminum than mature leaves. In roots, the average levels of phosphorus, calcium, iron, carbon and copper have dominated on those found in the leaves. Based on fertilizer inputs, it was found that this application has significantly influenced the content of elements in the organs except that of sulfur, aluminum, copper and manganese. In the second year of harvest, the results showed that the young leaves of Moringa are richer in moisture and ash, and leaf watches, on the other hand, have high levels of lipid, cellulose and proteins compared to young leaves. After our research, it is recommended to farmers that the best production of Moringa leaves and roots to associate mineral and organic fertilizer. However, an organic and mineral fertilizer combination amendment is necessary for optimum production on tropical soil, account keeping its organic matter content of the soil. This combination that led to the maintenance of soil organic matter contributes effectively to improving soil properties while promoting production for Moringa nutritional and therapeutic use.

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