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Reactions of cashew grafted seedlings to different formulas of mineral and organic fertilizers as bottom dressing in plantation

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ABSTRACT

The yield of raw cashew nuts in Benin remains relatively low, mainly because of the planting material used by farmers. Indeed, cashew tree producers use the nuts all-from previous years for the installation of plantations. The use of grafted seedlings is today an alternative, to improve the yield of new plantations. However, grafted plants are fragile and don't survive easily the dry season of the year in which they are planted, with a high mortality rate due to their fragility. This research conducted on tropical ferruginous soils in Central Benin aims to evaluate the reaction of grafted cashew seedlings to different formulas of mineral and organic fertilizers applied as bottom fertilization. For the study, a Randomized Complete Block Design with three repetitions was installed. Each repetition consists of 11 treatments. The generalized linear model (glm) was used to perform the analysis of variance with SPSS v21 software which to compare the effects of the treatments. The organo-mineral formulas $N_{40}P_{80}K_{72}$ + 2 kg of poultry droppings and $N_{40}P_{80}$ + 2 kg of poultry droppings applied as bottom manure allowed for better results in terms of recovery and growth parameters of grafted plants installed in the field. These fertilizer formulas allowed the grafted cashew plants to survive 85% and 80% respectively after installation. They also improved height growth, vigor and the ability to emit many leaves. To reduce the mortality rate of cashew transplants, these fertilizer formulas can be suggested to growers for the establishment of new plantations.
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Keywords: Bottom manure, Cashew transplants, Poultry Droppings, Mineral fertilizers, growth parameters, cashew grafted seedlings survival.

INTRODUCTION

The cashew tree (*Anacardium occidental* L.) is a cash and export crop in West African countries including Benin and helps to solve environmental and socio-economic problems in production areas (Hammed et al.,

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2008; Dwomoh et al., 2008). The importance of the cashew tree in Benin is increasing since the cotton crises of 1999-2000, which again revealed the fragility of the Beninese economy (Rondeux, 1999). Therefore, the Beninese state has taken to heart the diversification of sectors including that of cashew, and producers and economic operators have become aware of the importance of this sector, which has meanwhile been neglected. The cashew tree is now an engine of economic development that creates services and generates income for producers (Adegbola et al., 2011). In Benin, raw cashew nut represents the second agricultural export product after cotton and the third economic pillar (Issaka, 2019). This sector thus represented eight per cent of the total value of exports in 2008, 7% of agricultural GDP, 3% of national GDP and 24.87% of agricultural export income (Tandjiékpon, 2010). The annual cashew production in Benin is estimated at 110,117.41 tonnes, according to the yield survey report (DSA, 2017), with an average yield of 377 kg/ha, despite the efforts made by public authorities, for the promotion of the cashew sector, the yield (2-4 kg/tree) remains relatively low, compared to that of other countries such as Tanzania where the average yield is 15-20 kg / tree (Kodjo et al., 2016). These low yields are justified by the use of all-round planting material and unsuitable cultivation practices, in particular the lack of control over diseases and pests, the lack of maintenance of orchards, poor practices in the fields and post-harvest operations. To this must be added the very advanced age of the trees and the decline in soil fertility.

Maintaining fertility is a challenge that producers face. The soils under cashew groves have phosphorus deficiencies, ranging from 31 to 44 %, and potassium deficiencies ranging between 17 and 53 % (INRAB / CCA-CORAF, 2016). To correct the deficiencies and deficiencies in these two main nutrients, tests of formulations and doses of NPK mineral fertilizers were conducted in the minicipalicity of Parakou in North Benin. These tests made it possible to determine two formulations and two optimal doses appropriate to the cashew age classes of three to five years and seven to nine years, with a view to better management of soil fertility and improvement the cashew nut yield in plantations (INRAB / CCA-CORAF, 2016; N'Djolossè et al., 2018). These results are only avenues for improving the yield of young cashew plantations while the question of taking back in the field the new plant material (grafted plants) developed has not yet been resolved. Indeed, mortality rates of more than 73% and 68% were recorded, respectively in 2018 and 2019, according to the survey report of the URCPA-AD 2018 and 2019. The present study was initiated with a view to contributing to the reduction of mortality rates of grafted cashew trees after transplantation.

MATERIALS AND METHODS

Study environment

The work was carried out in the town of Save located at 8 ° 01 '59' 'North latitude and 2 ° 49' 01'' East longitude, at an altitude varying between 200 and 300 meters (Figure 1). Save District enjoys a tropical Sudanese-type climate marked by a rainy season and a dry season of 6 months each. The average rainfall is 1100 mm per year (Amadou, 2008). The heaviest rainfall occurs from June to September, with 587 mm of rain. The topography is marked by the presence of numerous rocky outcrops that appear in the form of domes. The vegetation is made up of savannah dotted with trees and shrubs. The average temperature in Save is 32°C throughout the year. The soils are tropical ferruginous soils which, due to human exploitation, give way in places to infertile lateritic soils. Hydromorphic soils are also observed in lowlands and in valleys (Amadou, 2008). The commune of Save is part of the communes of the Pole 4 Territorial Agency for Agricultural Development whose locomotive sector is cashew.

Methods

The trial was conducted in the open field for two consecutive years (2019 and 2020). Soil preparation and planting were carried out in May and June, respectively, each year. After cleaning the plot, the plant debris were burnt off the site, to prevent the decline in fertility by burning organic matter and microorganisms in the soil. The stakes were then set. The hole was made in June, at the level where the stakes were set up, measuring 50 cm in depth and in diameter. During this operation, the surface soil and the deep soil were deposited separately. The holes were filled with the mixture of topsoil and different types of fertilizer in the upper third of the holes two weeks after the holes were made to promote decomposition and mineralization of the organic matter. The deep soil layer served to complete the filling of the holes with dome formation. Holes with the appearance of a slight abutment are indicated by a stake placed in their center. The seedlings were planted in the center of the filled holes at the location of the stakes, two weeks after filling. To do this, a hole was regrooved in center, to the size of the polyethylene bag, then the base of the bag which contains the seedling was torn. To avoid injuring the plants, the holes have not been too tightly packed, taking care not to leave a hollow in the collar to avoid water stagnation that can cause root rot. The stakes were put back in place after planting in order to better locate the young plants installed. The maintenance of cashew trees was limited to regular weeding and phytosanitary treatment with Lambda-cyhalothryne and Acetamipridto to fight against pests. Before the application of fertilizers (ten form of solide fertilizer formulation), soil samples were taken from five points of the plot, following the diagonals, using an auger, to depths of 15 cm and 45 cm per collection point. The different samples were then mixed and the composition of the soil in organic matter, nitrogen (N), organic carbon (C), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na +) and potassium (K +) was determined in the Soil laboratory of the University of Abomey Calavi. The table of Igué et al. (2013), was used to assess the mineral content of the soil. In addition, rainfall data were recorded monthly to determine the amount of water that fell during the entire study period.

Experimental design

The experimental design is a randomized complete block with three replications. The treatments consisted of elementary plots of 10 plants each. A total of 110 plants were used per replicate and 330 for the entire trial. The 11 treatments were as follows:

- T0: without chemical fertilizer or organic manure (Control);
- T1: N_1P_1 or $N_{20}P_{40}$ (basic manure, single dose);
- T2: N_2P_2 or $N_{40}P_{80}$ (basic manure, double dose);
- T3: F1 (chicken manure added to basic manure, single dose);
- T4: F2 (chicken manure added to basic manure, double dose);
- T5: N_1P_1 + F1 or $N_{20}P_{40}$ + F1 (organo-mineral basic fertilizer, single dose);
- T6: N_2P_2 + F2 or $N_{40}P_{80}$ + F2 (organo-mineral basic fertilizer, double dose);
- T7: $N_1P_1K_1$ or $N_{20}P_{40}K_{36}$ (single dose basic manure with single dose of K);
- T8: $N_2P_2K_2$ or $N_{40}P_{80}K_{72}$ (double dose basic fertilizer with double dose of K);
- T9: $N_1P_1K_1$ + F1 or $N_{20}P_{40}K_{36}$ + F1 (single dose basic organo-mineral fertilizer with single dose of K);
- T10: $N_2P_2K_2$ + F2 or $N_{40}P_{80}K_{72}$ + F2 (double dose of organo-mineral basic manure and K).

The doses of fertilizer that made up the treatments are as follows:

Basic doses used per plants:

• N1: Nitrogen 20 grams of N (43.5 grams of Urea at 46%)

• P1: Phosphorus 40 grams of P_2O_5 (182 grams of 22% PCaS)

• K1: Potassium 36 grams of K_2O (60 grams of 60% KCl)

• F1: 20 grams of N + 16 grams of P_2O_5 + 20 grams of K_2O (1kg grams of chicken manure) (British Chamber of Agriculture, 2006)

• F2: 2F1

• P2: 2P1

• K2: 2K1

• N2: 2N1

Data collected

In order to assess the effect of fertilizers on the growth parameters of cashew plants seedlings after transplantation, the root collar diameter (DC) and height (H) of the plants were measured each month. These data made it possible to calculate the following parameters: the vigor (Vi) and the robustness (Ro) of the plants. The formulas used for this purpose are those developed by Fournier et al. (2015), for the calculation of the volume and the robustness while for the calculation of the vigor of the plants, the formula of Alexandre, (1977) was used. Plant height (H) is measured using a tape measure from root collar to apical bud each month. The root collar diameter (DC) of the plants is also determined using a caliper each month.

The formulas used are as follows:

$$Ro = \frac{\sqrt{CC}}{H}$$

$$Vi = \frac{H}{DC}$$

Vigor (Vi) is said to be good when the H/DC ratio is less than 80. The most vigorous plant is the one whose value of the ratio (H/DC) is lower. The hardiest plants are those with high hardiness values.

The length and width of five new leaves per plant per month are measured to calculate the leaf area of young plants. Five new leaves per plant were randomly selected. The length (L) of the leaves corresponds to the length of the leaf blade following the main vein (from the gland to the tip). The measurement of the width (l) is made on the widest part of the leaf and perpendicular to the main vein. The formula: SFT = NF x SF from Murthy et al. (1984) was used to calculate the total leaf area of plants with SFT = Total Leaf Area; NF = Number of Sheet; and leaves area of a leaf determined by the following relationship SF = 0.21 + 0.69 P with P = L x l; the number of resumed / successful plants to calculate the success / resumption rate by taking the number of successful plants out of the total number of plants planted.

For vegetative growth parameters, the data are expressed as growth rates calculated according to the following formula:

Growth rate for period i = $\frac{Xi-X0}{X0}$ with xi denoting the measurement at one collection period (each month) and X0 the initial measurement before the application of fertilizers (data from the first week after planting represent the reference data X0).

In order to assess the precocity of recovery and the development of the plants, the following data were collected: the number of leaves emitted per month by simple counting; the rate of appearance of the leaves calculated as the ratio between the total number of leaves and the number of months; the number of viable transplants to calculate the viability rate (Tv) or survival rate after plant establishment. The success rate is the ratio between the number of successful plants (alive) and the total number of plants transplanted: Ts = $\frac{NPR}{NTP}$ (NPR = Number of successful plants and NTP = Total number of plants transplanted in the field). The following formula is used to calculate the survival rate: $Tv = \frac{NPENF}{NTPEV}$ (with NPENF = the number of plants having produced new leaves, NTPEV = the total number of plants planted).

Statistical analysis

The data collected were entered and coded using the Excel 2013 spreadsheet. The spreadsheet was also used to produce the graphs and histograms. The data collected and the parameters calculated were subjected to statistical analyzes with the SPSS version 21 software for the analysis of variance (ANOVA) following the generalized linear model. In particular, the repeated measures ANOVA made it possible to compare the means of the data collected on several dates. In addition, the Pearson bivariate correlation coefficients and Spearman Rho made it possible to highlight the existing relationships between the parameters studied. The significance level for all the tests is 5%.

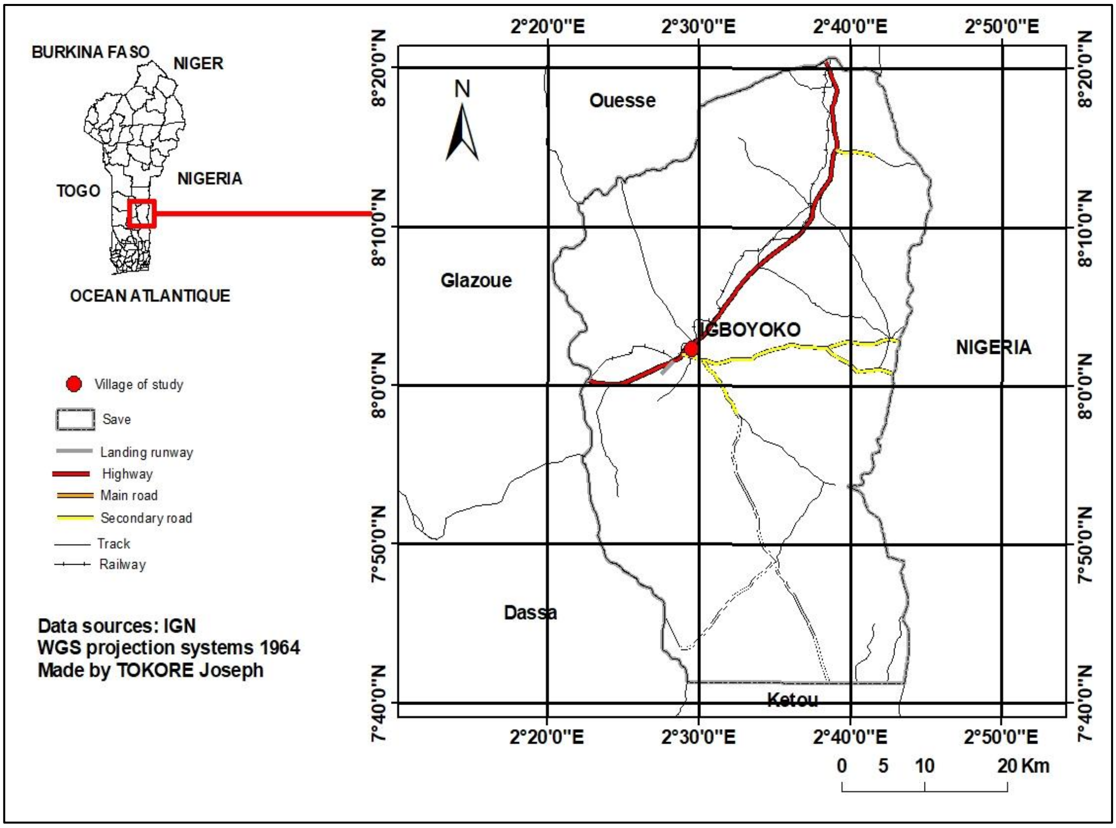


Figure 1: Map of the study area.

RESULTS

Physico-chemical characteristics of soils in the study site

The results of the analyzes of the soil samples taken are shown in Table 1. The acidity of the study area soils increases with depth. Also, the composition of organic matter and total nitrogen are greater at the surface (0-15cm) than at depth of 45 cm. In addition, the clay content is lower and the sand content is higher. However, it is loamy at depth of 45 cm. As for mineral elements, surface soils were rich in phosphorus, calcium, magnesium and nitrogen, while at a depth of 45 cm, the soil was richer in potassium. In sum, the analysis revealed that at a depth of 45 cm, acidity is important in the soil of the study area as well as the proportions of clay and silt. At 15 cm deep, on the contrary, the soils are rich in calcium, magnesium, sodium, nitrogen, potassium and organic carbon. After comparison with the characterization matrix of Igué et al. (2013), it can be concluded that the soils of the municipality of the study area have severe deficiencies in organic carbon (C), nitrogen (N) and phosphorus (P) while they are rich in potassium (K), especially when going from the surface to deeper horizons.

Rainfall variations in the town of Save

Figure 2 below shows the evolution of rainfall in the municipality of Save during the experiment, from April 2019 to June 2021, period of experimentation. The data was collected in conjunction with the ‘’Direction Départementale de l'Elevage et de la Pêche du Département des Collines’’. The rainy season starts from April and end in October with only a few rainy days in november and / or December. The rest of the months (November to march) of the year are dry. The peaks of the quantities of water fallen are observed between

September- October in 2019 while they are observed in June for the year 2020. These changes from one year to another shows the changing state of the climate of this Save area.

Variation in collar diameters and height of grafted cashew seedlings depending on the fertilizer formulas applied.

The analysis of variance showed that the different fertilizer formulas significantly improved the diameter and height of the plants ($P \leq 0.05$). The best average growth rates of the diameter at the root collar of the plants were obtained with the T6 treatment (0.71) followed by the T10 treatment (0.62). On the other hand, the lowest values were obtained with the T2 (0.5), T1 (0.51) and T0 (0.53) treatments. Figure 3 shows that the best growth rates in height of the plants were obtained with T10 ($N_{40}P_{80}K_{72}$ + F2), T5 ($N_{20}P_{40}$ + F1) and T6 ($N_{40}P_{80}$ + F2) while the lowest rates were obtained with the T1 ($N_{20}P_{40}$) and T0 (control) treatments. In summary, the T10 ($N_{40}P_{80}K_{72}$ + F2), T6 ($N_{40}P_{80}$ + F2) and T5 ($N_{20}P_{40}$ + F1) fertilizer formulas resulted in larger diameters and taller plants. The T1 ($N_{20}P_{40}$), T2 ($N_{40}P_{80}$ and T0 (control) treatments produced smaller diameters and smaller size plants. T6 ($N_{40}P_{80}$ + F2) was the treatment which favored the best stem growth of the plants starting from the 4th month of planting (Figure 4).

Robustness and vigor of young cashew trees depending on the fertilizer formulas

There is at least one significant difference between the different fertilizer formulas applied, for the vigor and robustness variables ($P \leq 0.05$). All the plants used for this experiment are vigorous (vigor less than 80). Three to four months after transplanting the plants to the field, the best vigor was obtained with the T9 treatment followed by the T0 and T2 treatments respectively. From the 7th to the 10th month after planting, the T6 treatment presented the most vigorous plants (Vi = 22) against the T10 and T4 treatments which presented the less vigorous plants even if the value Vi = 0.33 is less than 80 (Figure 5). Regarding the robustness of the plants (Figure 6), it was the T3 (0.011), T0 (0.010) and T1 (0.010) treatments that made it possible to obtain the most robust plants, unlike the T10 (0.009) treatment.

Rhythm of leaf appearance and total leaf area of the plants according to the different fertilizer formulas

At least one significant difference ($P \leq 0.05$) existed between treatments regarding the rates of leaf appearance and the leaf surfaces of cashew grafted plants from the second month of vegetation. We noted a highly significant difference ($P \leq 0.001$) from the 4th month after planting, for the leaf area even if this trend was observed from the 3rd month with regard to the rate of leaf appearance. The best rate of leaf appearance was obtained with the T10 and T6 treatments (Figure 7) while the lowest rate was obtained with the T1 and T2 treatments. Plants from T10 and T6 treatments produced an average of 4 leaves per month (Figure 8).

The largest leaf area was obtained with the plants which underwent the T10 treatment (Figure 8). They were followed respectively by those who received the T8 and T6 treatments. After 7 months of growth, it is the plants which received the T6 treatment (2 038.84 cm^2) which had the largest leaf areas. They were followed by those who underwent the T10 treatment (1 955.63 cm^2). However, the smallest leaf areas were obtained with the T3, T0 and T1 treatments. It should be noted that the treatments, which made it possible to obtain the best rates of leaf appearance, are the same ones that led to the obtaining of the largest leaf areas.

Success and survival rates of cashew seedlings after planting according to the fertilizer formulas

The analysis of Figure 9 shows that there is at least one significant difference ($P \leq 0.05$) between the different fertilizer formulas tested on the success and survival rate of grafted cashew seedlings after planting. The best rates of success and survival after planting were obtained respectively with the T10 and T6 treatments, while the lowest rates of success and survival after planting were obtained with the control. The T10 and T6 treatments made it possible to obtain 85 % and 80 % of live plants respectively after the dry period, which followed the year of transplanting of the plants. Regarding the survival rate after planting, it is rather the T6 treatment which has a better survival rate (90%) followed by T10 (85%). The lowest survival (45%) and success (30%) rates were obtained with the control treatment. From all the above, it emerges that the T6 treatment allowed the majority of the plants to survive after emitting new leaves, unlike the other treatments.

Correlations between the growth parameters studied

Correlation analysis revealed the existence of a significant correlation ($P \leq 0.05$) between the parameters studied. There is a strong positive correlation between collar diameter and plant height ($r = 0.71$) on vigor ($r = 0.51$) and total leaf area ($r = 0.78$) of cashew plants. This means that large size and diameter plants have high vigor with large leaf areas. Pearson's correlation analysis showed that the rate of leaf emergence is strongly and positively correlated with plant volume ($r = 0.69$) and total leaf area ($r = 0.80$). There is also a positive correlation between the total leaf area and the parameters which are correlated with the rate of appearance of the leaves, including the volume of the plants ($r = 0.84$). This means that the total leaf area of the plants evolves in the same direction as these parameters. Finally, the success rate after planting is positively correlated ($r = 0.35$) with the vigor of the plants. From this correlation analyzes, it appears that the T6 and T10 treatments developed more growth parameters that were strongly and positively correlated with each other. This allows them to stand out as the best treatments for obtaining very vigorous cashew seedlings after transplantation.

Table 1 : Physico-chemical characteristics of the different soil layers.

Ground depth	pH		Corg	Nt	A	L	S	P ass	K	Ca	Mg	Na
	H20	KCl	%	%		%		Ppm		(meq/100g)		
0-15 cm	6.03	5.55	1.12	0.46	6.00	11.40	80.94	11.63	1.12	5.57	8.11	4.97
0-45 cm	5.97	5.39	0.92	0.45	6.80	13.80	79.26	10.74	2.48	3.90	6.90	4.71

Legend: pH : Hydrogen potential ; Corg : Organic carbon ; Nt : Total nitrogen ; A : Clay ; L : Limon ; P ass : Assimilable phosphorus ; K : Potassium ; Ca : Calicium ; Mg : Magnesium ; Na : sodium ; H20 : water ; KCl : Sodium chloride.

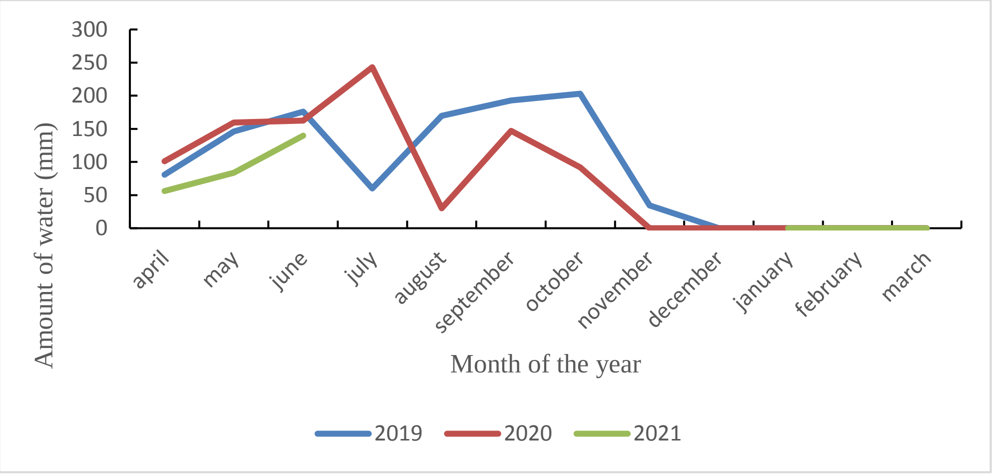
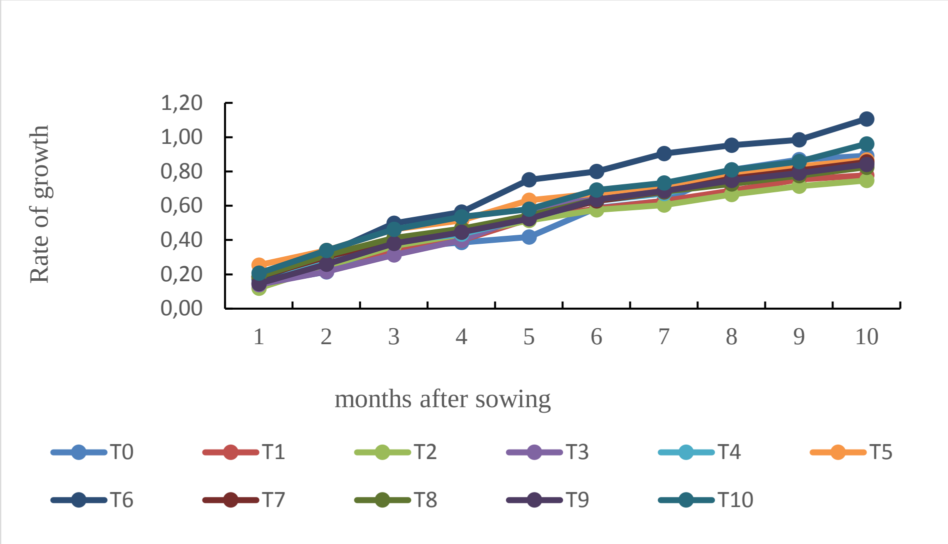
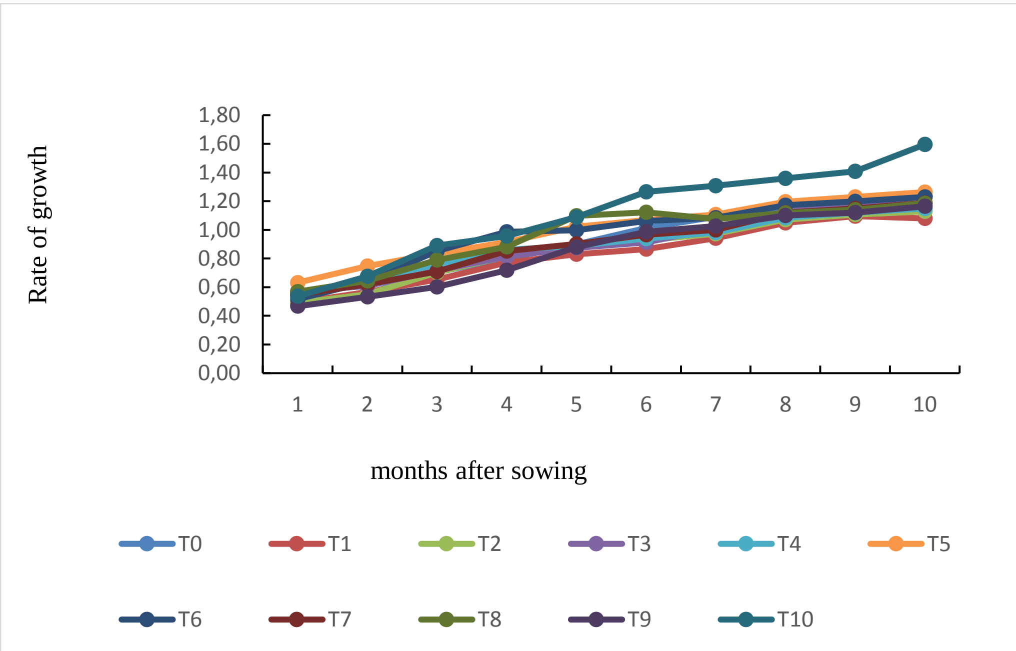


Figure 2: Rainfall evolution of the municipality of Save 2019-2021.



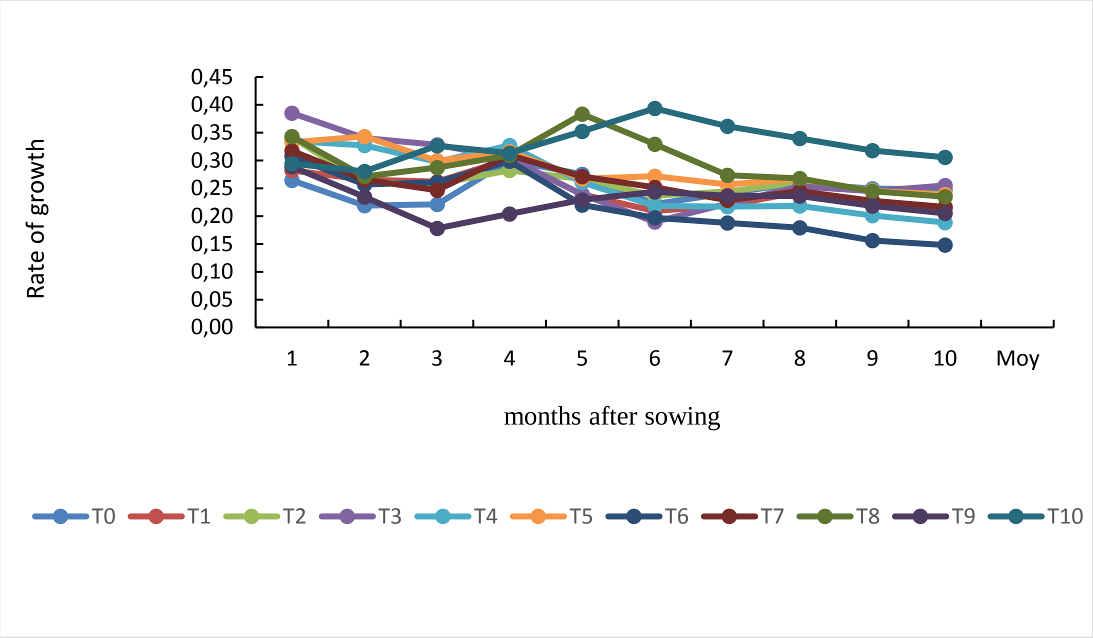
Legend : T0 : control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2

Figure 3 : Evolution of the root collar diameter of the plants during the first 10 months after planting.



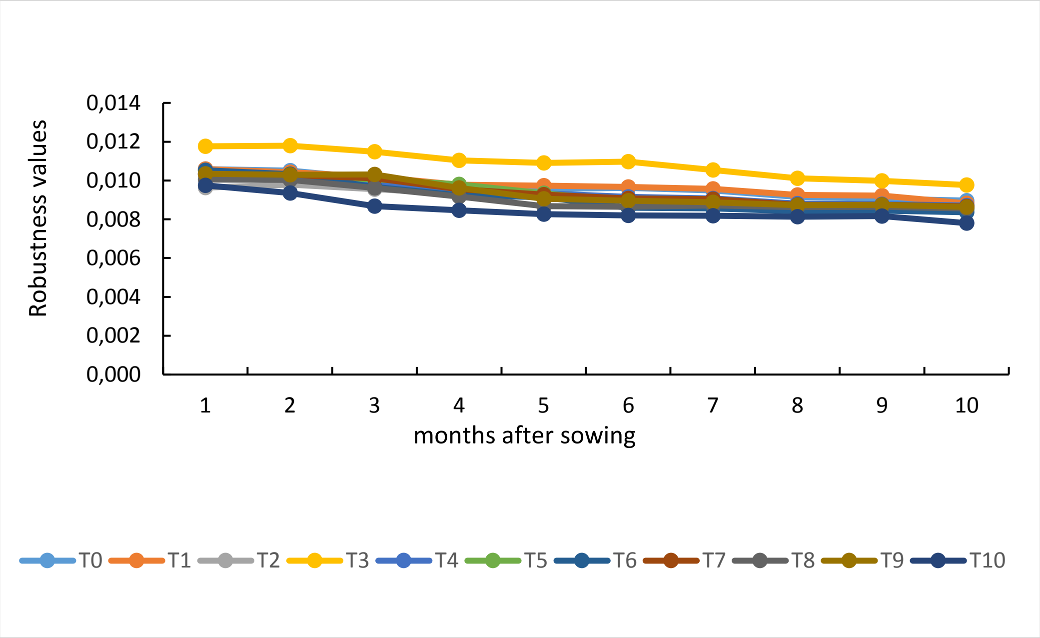
Legend : T0 : Control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2.

Figure 4: Heights of cashew seedlings planted in the field according to the fertilizer formulas 10 months after planting.



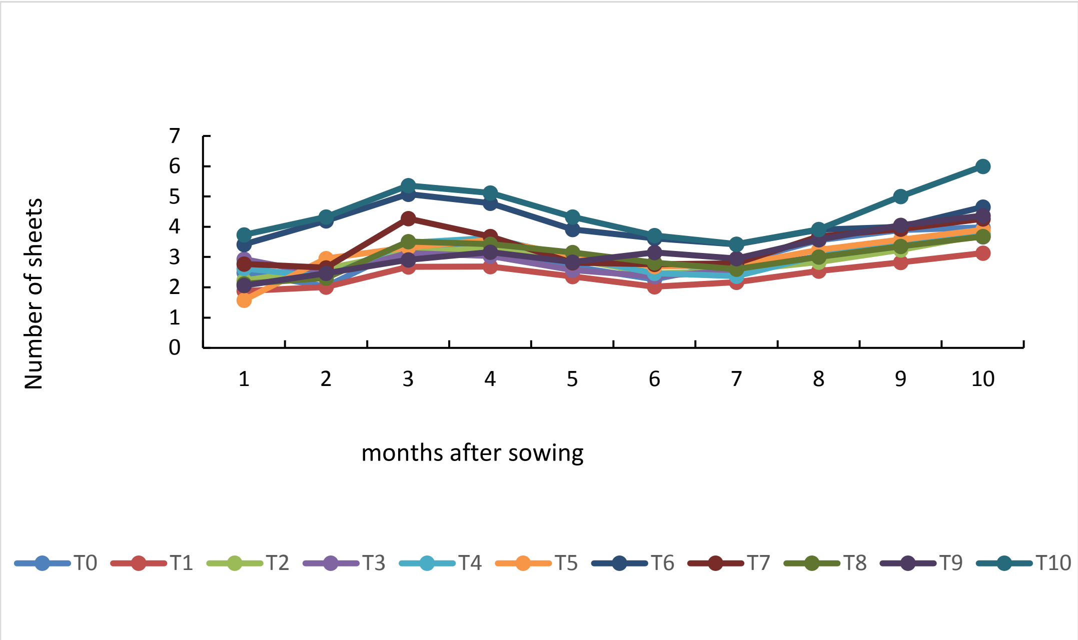
Legend : T0 : control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2.

Figure 5 : Vigor of cashew seedlings planted in the field according to the fertilizer formulas tested.



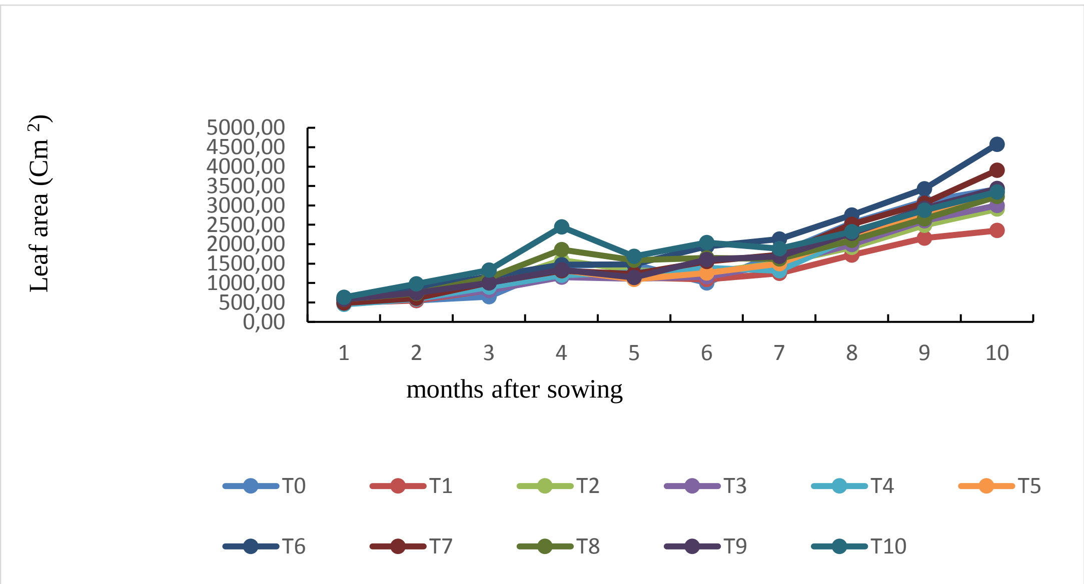
Legend : T0 : Control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2

Figure 6 : variation in the robustness of cashew seedlings planted in the field depending on the fertilizer formulas applied.



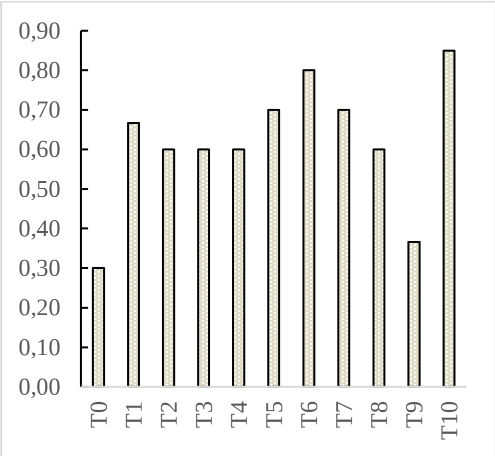
Legend : T0 : control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2.

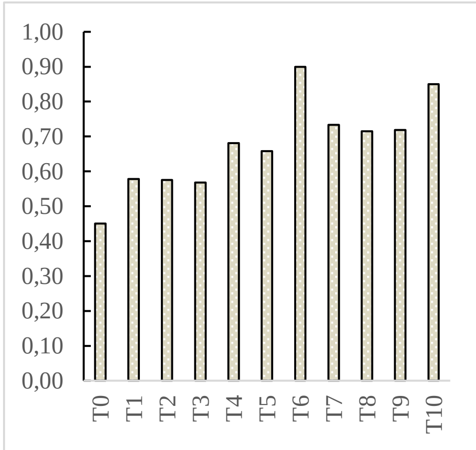
Figure 7 : variation in the rate of leaf appearance of cashew seedlings planted in the field depending on the fertilizer formulas tested.



Legend : T0 : Control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2.

Figure 8 : Variation in leaf area of cashew seedlings planted in the field according to the fertilizer formulas tested.





Legend : T0 : Control ; T1 = $N_{20}P_{40}$; T2 = $N_{40}P_{80}$; T3 = F1 ; T4 = F2 ; T5 = $N_{20}P_{40}$ + F1 ; T6 = $N_{40}P_{80}$ + F2 ; T7 : $N_{20}P_{40}K_{36}$; T8 : $N_{40}P_{80}K_{72}$; T9 : $N_{20}P_{40}K_{36}$ + F1 et T10 : $N_{40}P_{80}K_{72}$ + F2.

Figure 9a : Success rate after planting. **Figure 9b :** Survival rate after planting.

Figure 9 : success rate after planting and survival of grafted cashew seedlings planted in the field according to the fertilizer formulas tested.

DISCUSSION

This research revealed that the fertilizer formulas $N_{40}P_{80}K_{72}$ combined with 2 kg of poultry manure and $N_{40}P_{80}$ always combined with 2 kg of poultry manure resulted in larger diameters and taller cashew seedlings after transplantation. Plants given the $N_{20}P_{40}$, $N_{40}P_{80}$ or unfertilized exhibited smaller diameters and lower heights. The correlation analysis revealed on the one hand the existence of a strong positive correlation between the growth parameters (diameter and height) and the volume of the plants and on the other hand the existence of a negative correlation between the plant height and vigor. Thus, plants of large size and large diameter will be the most voluminous with a high vigor value (H / DC). However, the T6 treatment, i.e. the $N_{40}P_{80}$ + F2 fertilizer formula, was an exception to this rule by presenting vigorous plants despite the great heights presented. This peculiarity is explained by the constancy or the decrease in the value of the DC / H ratio. According to Leblanc (2016), a low amount of phosphorus in the soil causes plants to grow much more in diameter than in height. The $N_{40}P_{80}$ fertilizer formula combining a good proportion of nitrogen and phosphorus favored apical and cambial growth, respectively. This formula combined with poultry manure, which is also rich in mineral elements, and has an organic amendment property supported the effect of mineral fertilizers. The good vigor (Vi = 22 <80) observed in plants treated with the fertilizer formula $N_{40}P_{80}$ + F2 can be explained by the fact that these plants have developed a good root system favoring the mobilization of nutrients drawn from the soil. These results further explain the effect of the fertilizers applied. Indeed, these fertilizers made more readily available to the plant's adequate amounts of nutrients. This favored their growth and development, through the formation and installation of a good root system. These results corroborate those of Kambou et al. (2019), who showed that young plants and large diameter plants have a well-developed root system that allows them to mobilize nutrients from the soil. In fact, the quantities of nitrogen and phosphorus supplied have filled the gap in the stock of nutrients previously available in the soil. Thus, the quantities of nutrients that plants need to grow and develop have been achieved. In addition, the association of mineral and organic fertilizers could explain these results obtained because Akanza and Yao (2011) and Akanza (2015), have shown that the combinations of organic manure (poultry manure) and mineral fertilizers (NPK + urea + dolomite) show their effectiveness on the growth, production and yields of the cassava variety. The soils of the town of the study area where the experiment was conducted have a severe limitation in nitrogen and phosphorus, especially going from the surface to the underground layers, while these soils are unrestricted with regard to potassium. This was evidenced by the lack of difference between the effects of formulas containing potassium and non-potassium fertilizer formulas. The present study has indeed shown the beneficial effect of organic fertilizer applied in combination with mineral fertilizers such as NP, especially when the quantities of associated elements are in adequate proportions. The best rates of leaf appearance and the largest leaf areas were obtained with the fertilizer formulas $N_{40}P_{80}K_{72}$ associated with 2 kg of poultry manure and $N_{40}P_{80}$ associated with 2 kg of poultry manure while the lowest rate and the lowest leaf area were obtained with the $N_{20}P_{40}$ mineral fertilizer formulas, $N_{40}P_{80}$ and T0. These results explain once again that the combination of mineral and organic fertilizers allows good exploitation of soil nutrients through their easy accessibility to plants and in a sustained manner. Also, the positive correlation between the rate of appearance of new leaves, the total leaf area and the growth parameters (root collar diameter and height) may explain the results obtained with the formula $N_{40}P_{80}$ + 2 kg of poultry manure. The root system of cashew tree develops very quickly with a taproot that grows deeply, under favorable conditions. This allows new shoots to benefit from a significant supply of sap for their development as observed by the construction of large leaf areas in large diameter plants. Plants with a large leaf area are said to have a high capacity for receiving sunlight, which is favorable to the strong photosynthetic activity necessary for a good growth (Kambou et al., 2019). From all of the above, it emerges that the treatments which favored the growth of the plants more in height and/or in diameter presented the most voluminous plants more or less vigorous. The $N_{40}P_{80}$ organo-mineral fertilizer formula combined with organic fertilizer (poultry manure) produced vigorous plants with better growth parameters. On the other hand, those limiting the growth of the plants in diameter and or in height allowed the plants to have good vigor and therefore robust plants but of small volume.

The best success and survival rates after planting were obtained with the fertilizer formula $N_{40}P_{80}K_{72}$ + F2 and $N_{40}P_{80}$ + F2 while the lowest rates were obtained with the untreated plants. These treatments allowed most of the surviving plants to emit new leaves, unlike the other treatments, particularly those consisting solely of mineral fertilizers. The latter treatments even caused a regression in the survival rate of the plants after emission of new leaves. These results are due to the low quantity of organic matter and generally to the low fertility of the experimental site. Indeed, the soils of the experimental zone (municipality of Save) present a severe limitation in organic matter (organic matter rate <1%). Poultry manure, a good quality fertilizer (Hieronymus, 2001) provided organic matter, which is rapidly, mineralized (Chabalier et al., 2006). This made it possible to make the nutrients of mineral fertilizers easily accessible to the plants, which manage to draw them easily from the soil. This explains why the majority (85%) of plants treated with this fertilizer formula are kept alive.

Conclusion

This ten-month experiment, carried out from 2019 to 2020, revealed a significant difference between the effects of the fertilizer formulas on the parameters studied (survival rate, success rate after planting, root collar diameter, height, rate of leaf appearance, leaf area, vigor and robustness). The organo-mineral fertilizer formulas $N_{40}P_{80}$ + 2 kg of poultry droppings and $N_{40}P_{80}K_{72}$ + 2 kg of poultry droppings gave the best results in terms of effect on height, diameter, volume and vigor. These formulas allowed all the plants to survive after emitting new leaves. On the contrary, for the other treatments, a lower survival rate was observed after the emission of new leaves. To greatly reduce the mortality rate of grafted cashew trees, especially in the first years of planting in the field, we suggest that producers use an intensive cultivation system using organo-mineral fertilizer formulas.

COMPETING INTERETS

The authors declare that they have no competing interest in this article.

AUTHORS' CONTRIBUTIONS

SBJTOM and MBH: Study Design. AT: Data Collection. SBJTOM and AT: Data Analysis. SBJTOM: Project management. SBJTOM and MBH: Supervision of work. SBJTOM and MJA: Drafting of initial manuscript. SBJTOM, AJBD and JdeDFA: Manuscript review and editing.

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