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Growth, Development and Suitability for Kent of Mango Rootstocks on Soil Substrates Collected under *Anacardium occidentale* L., *Khaya senegalensis* (Desv.) A. Juss and *Mangifera indica* L., in Casamance, Senegal

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Abstract

With an overall contribution of nearly 4 billion CFA francs to Senegal's income, providing 23,000 employments more than 50% are women in 2021, the mango sector has shown its importance in the Senegalese economy even if the potential remains largely under-exploited. Thus, the study on the main local varieties remains an important perspective. This work carried out in the farm of the agroforestry department concerns the growth and development of four varieties (Pince, Kouloubadaseky, Sierra Leone and Diourou) on different soils (*Mangifera indica*, *Anacardium occidentale* and *Khaya senegalensis*). This work aims to contribute to the knowledge of the most cultivated varieties in Casamance. It is also a question of seeing the response of these varieties to grafting with the Kent variety. An experiment was conducted for one year with a split plot design consisting of 4 replicates (blocks). Each block contains 4 plots and each plot contains 3 sub-plots with 20 plants each. The parameters measured were: diameter at the collar, height, number of leaves, biomass, number of growth units and grafting success rate. The Sierra Leone variety showed the best growth results in terms of diameter at the crown (0.511 ± 0.090), leaf production (16 ± 2.52) and dry biomass (28.67 ± 16.80). The Kouloubadaseky variety had the best height record (41.90 ± 6.15) and the Diourou variety gave the best results in terms of fresh biomass (68.94 ± 30.90), number of growth units (9.350 ± 2.06) and grafting success rate (78.84%

± 29.44%). *Anacardium occidentale* soil substrate gave the best growth in height (39.73 ± 5.54 cm) while the substrate collected under *M. indica* L produced a greater number of leaves (13.14 ± 3.64) and grafting success rate (71.12% ± 37.25%). The *Khaya senegalensis* substrate recorded the highest values in biomass production (61.00 ± 35.93 for fresh biomass and 25.25% ± 15.74% for dry biomass).

Keywords

Mango, Substrate, Biomass, Grafting, Growth Unit, Kent

1. Introduction

Mango is the 7th most produced fruit in the world. Its production is over forty-five million tons in 2014 [1]. This production represents about 23% of the world's tropical fruit production, the main ones being banana, mango, pineapple, papaya, and avocado [2] [3]. The global production volume of mangos, mangosteens, and guavas reached 55.85 million metric tons in 2019, an increase from around 53.41 million metric tons in 2018 [4] behind the banana crop 106.7 Mt, apple 80.8 Mt, grape 77.2 Mt, and citrus 71.5 Mt [5]. Mango production is important in Senegal both for the local market and for export [6]. Indeed, Senegal exported 24,000 T of mango fruits in 2021 to European Union, Marocco and Arabic countries [7]. However, mango production is constrained by a number of problems: irregularity of production with alternating years of high and low production, heterogeneity of fruit at harvest (in terms of size or taste quality), and phenological asynchronisms with agronomic and phytosanitary impacts on production [8]. In Casamance, in addition to the above-mentioned problems, the mango sector faces several difficulties such as: the organization of producers, the proliferation of the fruit fly [9], the aging of orchards [10] [11] [12]. This is due to the fact that, in this area, populations depend for a significant part on forests and trees to satisfy various needs. With population growth, these resources are being depleted. Fortunately, many farmers would like to plant trees, but it is difficult to obtain high-quality seedlings. The production of basic information on germination, growth and development of local *Mangifera indica* varieties [13], as well as their suitability for grafting a semi-early variety such as Kent, could contribute to improving farmers' incomes. In addition, the use of litter from the main cash crop plantations in Casamance (*Mangifera indica* and *Anacardium occidentale*), but especially from forest species such as *Khaya senegalensis* (Desv.) A. Juss. would allow to improve growth performance in nurseries [13] at lower cost.

The general objective of this study is to contribute to a better knowledge of the local varieties of *M. indica* most widely grown in Casamance. Specifically, it aims to:

- Evaluate the growth and development capacities of these local varieties on

substrates derived from *M. indica*, *K. senegalensis* and *A. occidentale* substrates;

- Identify the best rootstocks of the Kent variety among these local varieties.

2. Materials and Methods

2.1. Presentation of the Site

The study was conducted on the farm of the Department of Agroforestry of the University Assane Seck of Ziguinchor (UASZ). It is located at 12˚32'54.88" North latitude and 16˚16'40.89" West longitude. This farm is in an area characterized by an average rainfall of 1200 mm per year [14]. Relative humidity is low in January, February and March under the influence of the harmattan. In August-September the air approaches its saturation point [15].

2.2. Materials

Mangifera indica L, *Anacardium occidentale* L and *Khaya senegalensis* substrates were used as soil in pol to grow mango seeds. Then, the collected soils were sieved to remove all impurities. Then, they were put in the sheaths. In addition, the blocks, plots and treatments were set up and marked with labels. The seeds were sown on July 27, 2019. Weeding was done every week.

Mango nuts of varieties were used as biological material during the study. The varieties are: Sierra Leone, Diourou, Pince and Kouloubadaseky. All the nuts come from the locality of Mlomp in the department of Oussouye. The nuts are identified morphologically. Diourou and Kouloubadaseky nuts have veins following furrows or canaliculi more pronounced in the former than in the latter. The veins follow shallow to superficial grooves in the Sierra Leone and Pince nuts (**Figure 1**).

2.3. Conduct of the Experiment

Field preparation began with clearing and staking of the plots. The nuts were sorted after a flotation test with water to determine the good seeds. The nuts were plunged into a wheelbarrow filled with water, the floating nuts were eliminated and those at the bottom of the wheelbarrow were selected for sowing [13].

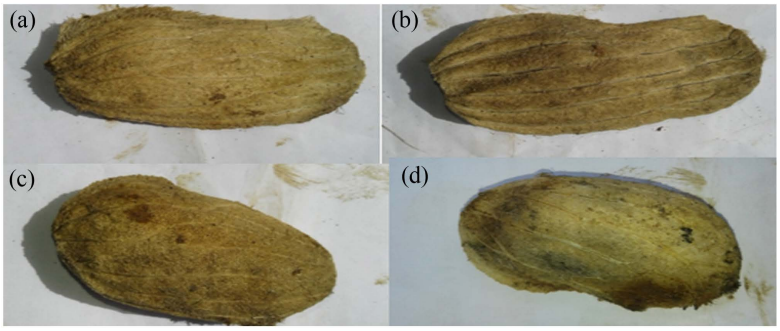

Figure 1. Walnuts from Kouloubadaseky (a), Diourou (b), Pince (c) and Sierra Leone (d) [13].

The experimental design set-up was a split plot with large plots corresponding to the four (4) varieties. Each large plot is divided into 3 small plots housing the substrates including the potting soil of *Anacardium occidentale*, *Khaya senegalensis* and *Mangifera indica*. The small plots receive the factor « substrate » and the large plots the factor "variety". To ensure good watering management, the plants in each plot are placed 25 cm apart between two successive plots in a block. The large plots are separated by 50 cm while the distance between 2 neighboring blocks is one meter. The number of treatments is 12 with 4 blocks and an elementary plot has 20 plants in pots (Figure 2).

The "Variety Factor" includes rootstocks such as Sierra Leone (Si), Diourou (Di), Pince (Pc) and Kouloubadaséky (Kl). The "Substrate Factor" includes *Anacardium occidentale* (Ao), *Khaya senegalensis* (Ks) and *Mangifera indica* (Mi). Their combinations give the following treatments: SiAo, SiKs, SiMi, DiAo, DiKs, DiMi, PcAo, PcKs, PcMi, KlAo, KlKs and KlMi.

At 6 month the growth parameters were evaluated for each plot. These parameters were the number of leaves, the crown diameter and the height from the crown to the terminal bud. Others parameters such as number of shoots, number of branches, number of central growth units were also evaluated. After a whole year of nursery, the plant central growth units (GU) were counted. The whole plant is thus constituted by a stack of growth units which are separated by circular scars or nodes (Figure 3).

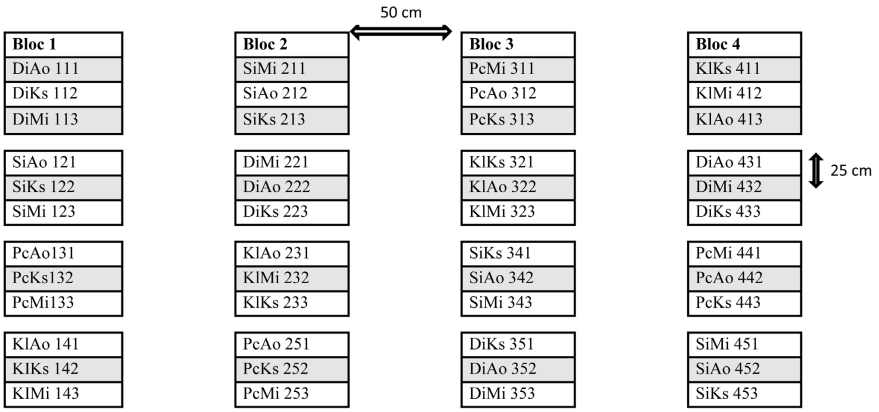

Figure 2. Split plot device housing the treatments.

Figure 3. Identification of central growth units.

2.4. Biomass Assessment

A random draw of the numbers assigned to the plants was made for each plot. Samples of three (3) plants per plot were removed, making 36 plants/block and 144 plants in total.

To evaluate the biomass, the plants were divided into aerial and root parts. The root part was well separated from the substrate. After rinsing with water, the roots were wrapped with tissue paper to absorb the water before weighing. The aerial part was divided into stems, branches and leaves. The fresh biomass of roots, stems and branches and leaves of each plant were determined by weighing with an electronic balance of precision 0.01 g. Afterwards, all parts of the plant were dried at 70˚C in the oven for 72 h and weighed to obtain the dry biomass (DB). -The total fresh and dry biomass was calculated according to the formulas:

$$TFB = FRB + FSBB + FLB$$

$$BDT = RDB + SBDB + LDB$$

Legend: TFB means Total Fresh Biomass; FRB means Fresh Root Biomass; FTBB means Fresh Stem and Branch Biomass; FLB means Fresh Leaf Biomass; TDB means Total Dry Biomass; RDM means Root Dry Mass; SBDB means Stem and Branch Dry Biomass; LDB means Leaf Dry Biomass.

The fractions of root, stem and branch and leaf biomass were calculated as the water content (WC) for all parts of the plant like the difference between fresh and dry biomass. The relative water content (RWC) was calculated as: RWC = (WC/Fresh Biomass) * 100.

These measurements were made at the Agroforestry and Forest Ecology Laboratory at UASZ (**Figure 4**).

2.5. Grafting Technic Used

Grafting of the Kent variety was used. The grafts came from orchards of Djibelor and Diabir around Ziguinchor district. The grafts in stop of growth are better for a fast recovery. A pruning is done before starting the grafting itself. The double slit method was used for all treatments. It is a method that allows for proper welding and maximizes the chances of success in *Mangifera indica*. Grafted

(a) (b)

Figure 4. (a): Electronic balance and (b): Oven.

plants were fellow-up to see the recovery. A regular monitoring was done every 3 days to observe the recovery and remove the buds from the rootstock variety. When recovery is noted, the plastic band was removed at the top of the graft not to block the evolution of the new shoots on the scion. The new shoots of the rootstock are regularly removed to avoid competition with the scion. Successful grafted plants were counted for each plot to calculate the success rate using the following formula.

Successful grafting rate per plot = (number of successful grafted plants per plot)/(total number of grafted plants per plot) * 100.

Data (number of leaves, height, collar diameter, number of shoots, number of growth units, biomass and successful grafting rate) was collected in the field, entered and processed on the Excel spreadsheet (Figure 5). The collected data were analyzed with the XLSTAT and Rplus softwares. Analyses of variance (ANOVA) were performed at the 5% threshold and comparison of means tests with Fisher's test. A principal component analysis (PCA) was performed to identify the correlations between the different variables studied (number of leaves, height, diameter, number of shoots, water content, central growth units) but also to characterize the varieties.

3. Results

3.1. Diameter at the Collar

As shown in Table 1, the collar diameter grown highly in the plant of the 3 varieties than in the variety Pince and the three other varieties (P = 0.006). Indeed, the variety Pince had the lowest diameter (0.384 ± 0.095). The Sierra Leone variety had the largest diameter (0.511 ± 0.090).

As shown in Table 2, the substrates had likely the same effect on the plant diameter (P = 0.588). The interaction between the two factors (variety and substrate) was not significant (P > 0.05) on the plant width growth.

Figure 5. Plant from a successful graft.

Table 1. Diameter at the collar per variety.

Varieties	Diameter (cm)
Diourou	0.498 (±0.073) **b**
Kouloubadaseky	0.468 (±0.084) **b**
Pince	0.384 (±0.095) **a**
Sierra Leone	0.511 (±0.090) **b**
Mean	**0.465**
P-value	**0.006**

Table 2. Diameter of seedlings according to substrates.

Substrates	Diameter (cm)
Anacardium occidentale	0.472 (±0.090) **a**
Khaya senegalensis	0.472 (±0.111) **a**
Mangifera indica	0.453 (±0.093) **a**
Mean	**0.466**
P-value	**0.588**

3.2. Plant Height

Table 3 presents the variation of the average height according to the varieties. There is no difference between varieties (P = 0.226). However, the Kouloubadaseky variety has the maximum value (41.90 cm) and the Pince variety the minimum value (31.78 cm). The varieties Kouloubadaseky and Sierra Leone had a faster growth in height than the others.

Table 4 presents the effect of the substrate on the plant height. As shown there is no significant difference from between the three types of soil (P = 0.319). However, *Anacardium occidentale* potting soil induced 1 cm more of height comparing the other substrates.

The interaction between the two factors was not significant (P > 0.05).

3.3. Number of Leaves

Table 5 presents the average number of leaves per variety. Statistical analysis does not reveal any significant difference between varieties (P = 0.219). However, the variety Sierra Leone recorded the highest number of leaves (16 ± 2.52) and the lowest numbers of leaves were recorded by the varieties Kouloubadaseky and Pince (11 ± 1.25; 11 ± 1.67). The variety Sierra Leone produced the highest number of leaves compared to the other varieties.

Table 6 presents the number of leaves of the plants according to the soils. It appears from this table that there is no significant difference between the plants according to the soils (P = 0.311).

Table 3. Height by variety.

Varieties	Height (cm)
Diourou	40.28 (±4.16) **a**
Kouloubadaseky	41.90 (±6.15) **a**
Pince	31.78 (±2.06) **a**
Sierra Leone	41.17 (±2.81) **a**
Mean	**38.78**
P-value	**0.226**

Table 4. Height of the plants per type of substrate.

Substrates	Height (cm)
Anacardium occidentale	39.73 (±5.54) **a**
Khaya senegalensis	38.43 (±6.12) **a**
Mangifera indica	38.19 (±5.75) **a**
Mean	**38.78**
P-value	**0.319**

Table 5. Number of leaves per variety.

Varieties	Number of leaves
Diourou	13 (±1.16) **a**
Kouloubadaseky	11 (±1.25) **a**
Pince	11 (±1.67) **a**
Sierra Leone	16 (±2.52) **a**
Mean	**12.91**
P-value	**0.219**

Table 6. Number of leaves produced by the plants per soil substrate.

Substrates	Number of leaves
Anacardium occidentale	12.75 (±2.05) **a**
Khaya senegalensis	12.84 (±2.10) **a**
Mangifera indica	13.14 (±3.64) **a**
Mean	**12.91**
P-value	**0.311**

Figure 6 shows the variation of the number of leaves according to the varieties and soils. The analysis of variance shows a higher significant difference between plants treatments (P = 0.0001). The SiMg treatment recorded the highest number of leaves (18 leaves). The DiMi, DiKs, SiKs and SiAo treatments show intermediate values in terms of number of leaves.

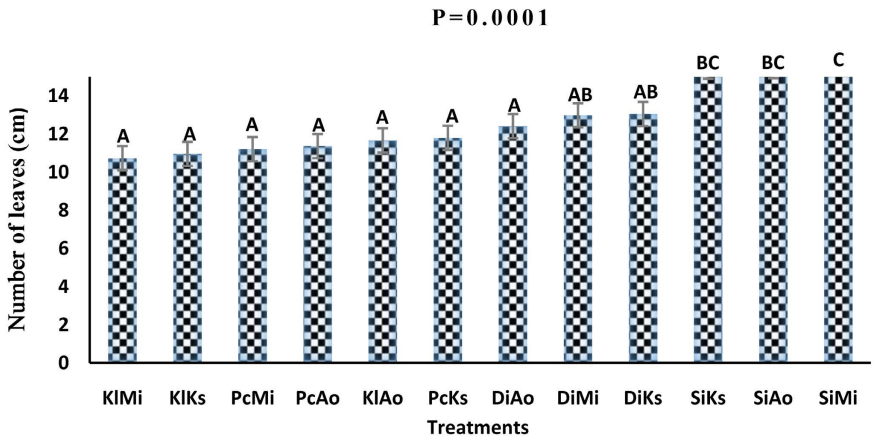

Figure 6. Variation of the plant leaf number per treatment.

3.4. Biomass

3.4.1. Fresh Biomass

Table 7 presents the fraction of fresh biomass according to the varieties. Statistical analysis reveals a significant difference between varieties (P = 0.0001) with two groups (a and b) at the level of the different plant parts (leaves, stems and roots). The Diourou variety recorded the highest fresh above-ground biomass (30.17 ± 14.28 g for leaves and 22.44 ± 10.96 g for stems) and even for the below-ground biomass (16.33 ± 7.92 g). On the other hand, the variety Pince gives the lowest values (15.22 ± 8.25 g for leaves, 8.56 ± 5.25 g for stems and 8.69 ± 5.41 g for roots).

Table 8 gives the fraction of fresh biomass produced by the plants grown on different soils. It appears from this table that the plants yield the same amount of biomass whatever the substrates (for leaf biomass P = 0.234, stem fresh biomass P = 0.277 and root fresh biomass P = 0.337). However, in absolute value, the *Khaya senegalensis* substrate came first in terms of fresh biomass production for leaves (27.17 g ± 16.13), for roots (14.73 g ± 8.62) and for stems (18.69 g ± 13.34).

The interaction between the two factors was not significant all fraction of fresh biomass (leaves, stems, branches and roots).

3.4.2. Dry Biomass

Table 9 presents the fraction of dry biomass by variety. The statistical analysis shows a higher significant difference (P = 0.0001) between varieties for the different parts of the plant. The variety Diourou gives the highest dry biomass fractions for stems (8.64 g ± 4.22) while the variety Sierra Leone records the highest value for leaves (12.58 ± 6.75) and roots (7.53 g ± 4.82). The variety Pince has almost half the values recorded for the other varieties, for leaves (5.75 g ± 3.08), stems (3.47 g ± 2.68) and roots (3.56 g ± 1.66). The Sierra Leone variety recorded the highest total dry biomass fraction (28.67 g ± 16.80).

Table 10 shows the fraction of dry biomass by soil. Statistical analysis shows that there is no difference between the substrates for the dry biomass of leaves

Table 7. Fraction of fresh biomass produced/plant for each variety.

Varieties	Leaves (g)	Stems (g)	Roots (g)	BF total (g)
Diourou	30.17 (±14.28) **b**	22.44 (±10.96) **b**	16.33 (±7.92) **b**	68.94 (±30.90) **b**
Kouloubadaseky	28.53 (±13.75) **b**	18.81 (±10.73) **b**	16.08 (±7.85) **b**	63.42 (±28.06) **b**
Pince	15.22 (±8.25) **a**	8.56 (±5.25) **a**	8.69 (±5.41) **a**	32.47 (±17.50) **a**
Sierra Leone	28.67 (±13.27) **b**	19.50 (±13.61) **b**	14.69 (±7.97) **b**	62.86 (±32.11) **b**
Mean	**25.65**	**17.33**	**13.95**	**56.92**
P-value	**0.0001**	**0.0001**	**0.0001**	**0.0001**

Table 8. Fraction of fresh biomass/plant according to the substrate.

Substrates	Leaves (g)	Stems (g)	Roots (g)	Total (g)
Anacardium occidentale	25.17 (±13.91) **a**	16.38 (±11.50) **a**	14.17 (±7.96) **a**	55.71 (±30.35) **a**
Khaya senegalensis	27.58 (±16.13) **a**	18.69 (±13.34) **a**	14.73 (±8.62) **a**	61.00 (±35.93) **a**
Mangifera indica	24.19 (±11.26) **a**	16.92 (±10.25) **a**	12.96 (±7.20) **a**	54.06 (±26.12) **a**
Mean	**25.65**	**17.33**	**13.95**	**56.92**
P-value	**0.234**	**0.337**	**0.277**	**0.276**

Table 9. Dry biomass fraction by variety.

Varieties	Leaves (g)	Stems (g)	Roots (g)	Total (g)
Diourou	12.25 (±5.24) **b**	8.64 (±4.22) **c**	7.36 (±3.10) **b**	28.25 (±11.90) **b**
Kouloubadaseky	11.22 (±5.39) **b**	6.19 (±3.45) **b**	6.53 (±3.12) **b**	23.94 (±10.65) **b**
Pince	5.75 (±3.08) **a**	3.47 (±2.68) **a**	3.56 (±1.66) **a**	12.78 (±6.68) **a**
Sierra Leone	12.58 (±6.75) **b**	8.56 (±6.27) **c**	7.53 (±4.82) **b**	28.67 (±16.80) **b**
Mean	**10.45**	**6.72**	**6.24**	**23.41**
P-value	**0.0001**	**0.0001**	**0.0001**	**0.00001**

Table 10. Dry biomass fraction according to soils.

Substrates	Leaves (g)	Stems (g)	Roots (g)	Total (g)
Anacardium occidentale	10.60 (±5.79) **a**	6.17 (±4.50) **a**	6.23 (±3.46) **a**	23.00 (±12.83) **a**
Khaya senegalensis	11.21 (±6.56) **a**	7.54 (±5.41) **a**	6.50 (±4.34) **a**	25.25 (±15.74) **a**
Mangifera indica	9.54 (±5.34) **a**	6.44 (±4.44) **a**	6.00 (±3.27) **a**	21.98 (±11.89) **a**
Mean	**10.45**	**6.72**	**6.24**	**23.41**
P-value	**0.170**	**0.163**	**0.511**	**0.240**

(P = 0.170), roots (0.511) and stems (0.163). However, *Khaya senegalensis* potting soil gave the highest values of dry biomass of leaves (11.21 ± 6.56), roots (6.50 ± 4.34) and stems (7.54 ± 5.41).

3.4.3. Moisture Content (%)

Table 11 presents the moisture content (%) by variety. Kouloubadaseky variety contained much water than Sierra Leone variety (P = 0.004). The Kouloubadaseky variety has the highest moisture content (61.66% ± 8.27%) and the Sierra Leone variety has the lowest (54.94% ± 10.38%). However, Diourou and Pince had an intermediate moisture rate.

Grafting success rate with Kent variety

Grafting success rate according to varieties and soils

Table 12 shows the grafting success rate by variety. The analysis of variance shows that there is a higher significant difference between the variety Diourou and Pince (P = 0.005). The Pince variety stands out from the others with its low rate (38.75% ± 41.79%). The Diourou variety is better in grafting because of its high rate (78.84% ± 29.44%). Even though this grafting success rate is not significantly different from those recorded by Kouloubadaseky and Sierra Leone.

Table 13 presents the grafting success rate according to the soils. The analysis of variance shows that there is no significant difference in the grafting success rate between plants according to the substrates (P = 0.408). However, Mangifera

Table 11. Moisture content by variety.

Varieties	*Moisture content* %
Diourou	57.70 (±7.26) **ab**
Kouloubadaseky	61.66 (±8.27) **b**
Pince	58.50 (±12.64) **ab**
Sierra Leone	54.94 (±10.38) **a**
Mean	**58.20**
P-value	**0.004**

Table 12. Grafting success rate by variety.

Varieties	*Grafting success rate* (%)
Diourou	78.84 (±29.44) **b**
Kouloubadaseky	74.48 (±30.64) **b**
Pince	38.75 (±41.79) **a**
Sierra Leone	70.73 (±29.34) **b**
Mean	**65.70**
P-value	**0.005**

Table 13. Grafting success rate of seedlings according to substrates.

Substrates	Grafting rate (%)
Anacardium occidentale	70.38 (±34.83) **a**
Khaya senegalensis	55.62 (±35.68) **a**
Mangifera indica	71.12 (±37.25) **a**
Mean	**65.70**
P-value	**0.408**

indica potting soil had the highest rate (71.12% ± 34.83%) and *Khaya senegalensis* soil substrate recorded the lowest rate (55.62% ± 35.68%).

Regarding the grafting success rate of seedlings there were not interaction between the two factors ("variety" and "ligneous potting soil").

4. Central Growth Unit (CGU)

Table 14 presents the number of growth units according to the varieties. The analysis of variance shows significant difference between the Diourou variety (9.35 ± 2.06) and the Pince variety (6.40 ± 2.42) with a probability of 0.0001. The Diourou variety has the highest number of central growth units (9.35 ± 2.06) followed by Sierra Leone (9.17 ± 2.25) and Kouloubadaseky (7.27 ± 3.04); the Pince variety gives the lowest value (6.40 ± 2.42).

Relation between the variables evaluated and the different treatments

Through the principal components analysis (PCA) carried out, Figure 7 presents the distribution of treatments according to the variables measured on the plants.

The F1 and F2 axes indicate 93.26% of the variability studied. Water content (48.6%), number of leaves (20%), successful grafting (14.7%) and plant height (11.3%) contributed 94.4% to the formation of the F2 axis. However, diameter (14.6%), dry biomass stem (14%), leaf (13.9%) and root (12.9%), plant height (11.2%), grafting success (9.7%) and number of growth units (9.7%) contribute to 89.1% on the formation of the F1 axis (Figure 7).

The growth in height of the plants is weakly related to the water content or the number of leaves and also the number of growth units. It is closely linked to the diameter at the base and to the amount of dry matter, so varieties that produce more dry matter at the stem, leaf and root, and therefore have good radial growth, are successful in grafting with Kent. The Diourou and Kouloubadaseky varieties seem to be the best rootstocks for Kent and to a lesser extent Siera léone. The variety Pince is the least successful and potentially weakest rootstock for Kent.

The substrates seem to have the same effect on the growth parameters of the seedlings. The emission of growth units seems to be more related to the total biomass (leaf, stem, root), and the diameter of the plant with significant correlations (Table 15). However, the elongation of growth units was not evaluated.

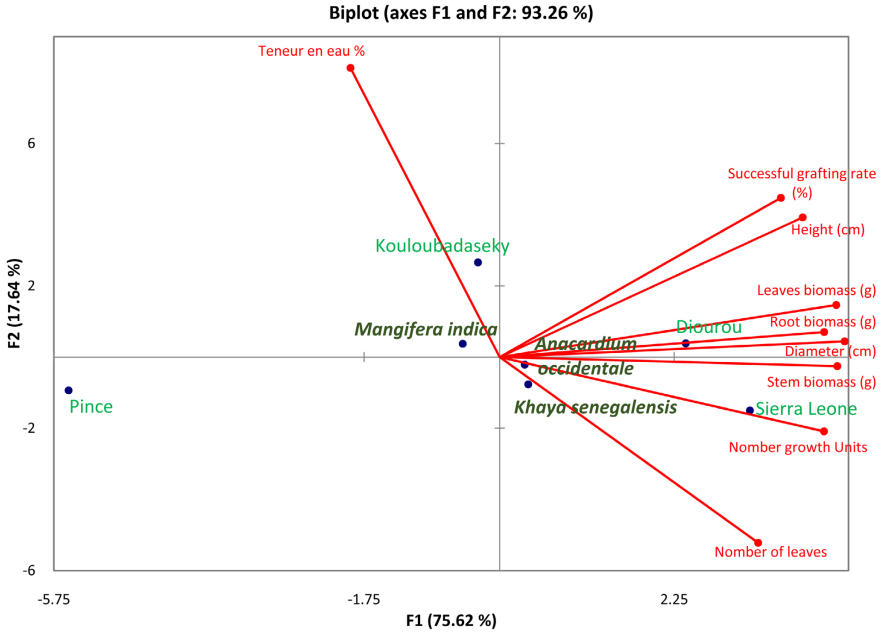

Figure 7. Distribution of substrates and varieties according to the variables assessed.

Table 14. Number of growth units per variety.

Varieties	Number CGU
Sierra Leone	9.17 (±2.25) **b**
Diourou	9.35 (±2.06) **b**
Kouloubadaseky	7.27 (±3.04) **a**
Pince	6.40 (±2.42) **a**
Mean	**8.05**
P-value	**0.0001**

Table 15. Correlation between variables.

Variables	Height (cm)	Number leaves	Diameter (cm)	Leaves weight (g)	Stem weight (g)	Roots weight (g)	Moisture %	Succeed grafting (%)	Number CGU
Height (cm)	**1**								
Number feuilles	0.433	**1**							
Diameter (cm)	**0.905**	0.705	**1**						
Leaves weight (g)	**0.934**	0.602	**0.987**	**1**					
Stem weight (g)	**0.802**	0.730	**0.964**	**0.935**	**1**				
Roots weight (g)	**0.846**	0.625	**0.938**	**0.955**	**0.888**	**1**			
Moisture %	−0.027	**−0.772**	−0.396	−0.294	−0.416	−0.338	**1**		
Succeed grafting (%)	**0.901**	0.377	**0.815**	**0.813**	**0.778**	0.722	0.077	**1**	
Number CGU	0.674	**0.781**	**0.912**	**0.856**	**0.963**	**0.825**	−0.598	0.685	**1**

5. Discussion

The plant height was almost same in all the 4 mango varieties and regarding the substrates. These results corroborate those of Djaha *et al*., [16], who studied the growth and suitability of two *Anacardium occidentale* genotypes used as rootstocks in Côte d'Ivoire, and found no significant difference between the different genotypes. This analysis also showed that there was no significant difference in plant height between the different soils (P = 0.319). These results are similar to those of Ndiaye *et al.* [13] who also showed that the effect of soil substrates was not felt on plant height. Mané, [17] studied the germination and growth of *Acacia melifera* (Vahl) Benth. on *Faidherbia albida* (Del.) A. Chev, *Elaeis guineensis* Jacq. and *Anacardium occidentale* L. and found a significant difference in seedling height between soils. The height was changing rapidly during the rainy season, which is due to the availability of water; this confirms the statements of Schaffer *et al.* [18] who showed that environmental factors, temperature and water availability remain the most important in the growth of certain species. Douma *et al*., [19] showed the effect irrigation regime on germination and nursery growth of *Parkia biglobosa* Jacq.

The diameter at the collar measures 4.66 mm in 3 months in Casamance. A higher growth record was reported at Banfora (Burkina) by Bognina [20] A. *occidentale* L accessions whose plants reach 5.85 mm in 2 months. The diameter growth was different from a variety to another and between treatments. The Sierra Leone variety has a larger diameter than the Pince variety. Similarly, the Kouloubadaseky variety showed a higher difference in diameter on cashew potting soil than on *M. indica* and *K. senegalensis*. These results confirm those of Ndiaye *et al*., [13], who also showed that the Kouloubadaseky variety had a diameter that varied according to the soil fertility. This is confirmed by Giffard [21] who states that *Faidherbia albida* (Del.) A. Chev. soil substrate is rich in NPK fertilizer. Benmahioul *et al*., [22] also showed positive effects of substrate on the growth of young plants of *Pistacia veral*. L. Similarly Choungo *et al*., [23] noted a significant difference between treatments of *Irvingia wombolu* Hook f. species.

The number of leaves of the varieties ranged from 11 to 16 leaves giving an average of 13 leaves. This average number can be comparable to the results obtained by Some [24] and Bognina [20], who counted 14 leaves for *A. occidentale* L. plants. Then Diourou variety produces more leaves (12.25 g), stems and branches (8.64 g) on the other hand the Sierra Leone variety develops more root biomass (7.53 g). Statistical analysis revealed a significant difference between treatments (varieties combined with substrates) in leaf area (P = 0.0001). This assertion confirms the results of Mané [17], who showed a significant difference in leaf biomass between treatments. But there was no significant difference between treatments at root level (P = 0.055) and at stem + branch level (P = 0.065). Similar results were also reported by Ndiaye *et al.* [25], who noted that there is no significant difference on biomass at root and leaf level between treatments

related to *Moringa oleifera* Lam. species. The varieties combined with *K. senegalensis* (Dres.) A. Juss. substrate gave the highest fractions in all levels (SiKs (8.58 g) for roots, SiKs (10 g) for stems and branches and KlKs (13.83 g) for leaves). Statistical analysis shows that there is a highly significant difference between varieties (P = 0.0001). The variety Diourou gives the highest number of Central Growth Units (9 CGUs) compared to the others. Regarding the treatments (varieties combined with substrates) there is a significant difference (P = 0.0001). The DiAo treatment (Diourou variety & *A. occidentale* potting soil) gave the highest number of CGUs (9.75), which confirms the effectiveness of the Diourou variety. The presence of CGUs confirms that *M. indica* has a rhythmic growth which is said by Magne [26], the growth of *M. indica* is translated by rhythmic vegetative growth and these growths are translated by the emission of CGUs. The rate of success in grafting was 65.70%. *M. indica* L responds well to grafting. Ohler [27] confirms that grafting succeeds more quickly on young plants. A difference is noted between the used mango varieties. The variety Diourou gives a better successfull grafting rate (78.84%) with the variety of Kent. A difference was also noted between treatments; the KlMi treatment (Kouloubadaseky & *M. indica* L. potting soil) gave the best rate of 91.42%. These results are contrary to those obtained by Bognina [25], in *A. occidentale*. Between the soils, the analysis shows that there is no difference, but in absolute value the *M. indica* L. soil gives a better grafting success rate (71.12%). In conclusion, Diourou, Kouloubadaseky and Sierra Leone varities responded better pince when grafted with Kent while the *M. indica* L. potting soil gives a better response to grafting.

6. Conclusion

From this study, it appears that the growth and development of four varieties (Pince, Diourou, Sierra Leone and Kouloubadaseky) on substrates (*M. indica* L., *A. occidentale* L. and *K. senegalensis* (Dres.) A. Juss.) and their grafting efficiency with the Kent variety gave good opportunities to farmers. Indeed, the results showed that Sierra Leone variety gives a better growth in diameter and number of leaves, while Kouloubadaseky variety gives a better growth in height. The variety Diourou gives the best results for all the other remaining parameters. Even there was no significant difference, the *M. indica* L. potting soil maintained water content and gave the best results on the diameter and the successful grafting rate; the *A. occidentale* potting soil gave the best results in height. Finally, the *K. senegalensis* potting soil gives the best results in terms of biomass production. Diourou, Kouloubadaseky and Sierra Leone varities responded better Pince when grafted with Kent. *M. indica* L. and *K. senegalensis* soils are better in terms of growth of these varieties.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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