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Morphometric parameters, cashew (*Anacardium occidentale* L.) nuts germination and graft plant production time in Côte d'Ivoire

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ABSTRACT

The production of grafted cashew seedlings in Côte d'Ivoire lasts from four to six months. This causes late transplanting in the field. This study aimed at reducing the production time of grafted cashew plants. The effect of cashew nut morphometric parameters on germination, rootstock vigour and production time of grafted cashew seedlings was evaluated. Four genotypes, characterized by different nut sizes, were used as rootstocks. For sowing, 160 cashew nuts were used. Apical grafting, with semi-woody scions taken from trees of genotype LAX3264, was carried out on the rootstocks. Little variability was found in the length, width and thickness of the nut. On the contrary, the nut weight showed a high variability. Seed germination time was on average 5-8 days after sowing (DAS). The small nuts, from the PK23 genotype, had a long germination time. The production time of the grafted plants, on average 72 days after sowing, for all the genotypes, was shorter than the former production time which was 90 and 120 days. No significant differences were observed between the genotypes.

Keywords: Cashew, germination, morphometric parameters, rootstock vigour.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) was introduced in the north of Côte d'Ivoire in 1959, with the aim of combating deforestation and soil degradation (Silué, 2020). Cashew is currently a major cash crop in Côte d'Ivoire. Due to the importance of cashew nuts on the international market and the ease of setting up and running orchards, more people have taken up cashew cultivation in recent years. This has resulted in an increase in the area under cultivation from 500,000 ha in 2006 to 1,350,000 ha in 2018 (FIRCA, 2018). The consequence is an increase in Ivorian cashew nut production from 235,000 tonnes in 2006 to 738,000 tonnes in 2018 (FIRCA, 2018), making Côte d'Ivoire the world's leading producer of cashew raw nuts. However, the nut yield from the orchards remains low. It is around 524 kg/ha due to the use of low-performance plant material, consisting of raw nuts and the use of inappropriate cultivation practices by the majority of producers. On the contrary, in India, Brazil and Vietnam, the main producing countries and users of high-

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performance varieties, the nut yield in orchards is at least 1 tonne.

In recent years, Côte d'Ivoire has set itself the objective of increasing the yield of its orchards and improving the quality of its cashew nuts. It has therefore committed the National Agricultural Research Centre to the development of high-performance plant material. Three high-producing cashew genotypes were selected. They are propagated as grafted plants in private nurseries and made available to producers. However, the production period for grafted cashew seedlings in Côte d'Ivoire is long. It varies from four to six months. This is due to the fact that, because of the lack of grafters in private nurseries, rootstocks are sometimes grafted at least 90 days old after emergence. Djaha et al. (2012) have shown that the success rate of grafting in cashew decreases with the age of the rootstock. In addition, the long stay of grafted cashew plants in the nursery leads to the depletion of mineral elements in the substrates contained in the pots.

The taproot also penetrates the base of the pot into the soil if the pots are placed directly on the ground. It is therefore necessary to reduce the production time of grafted cashew plants. Several approaches are possible to achieve this. For example, the growth of young rootstocks can be accelerated by providing nitrogen fertiliser to young plants in the nursery, as was done by Tokoré et al. (2021).

The present study aimed at evaluating the effect of cashew nut morphometric parameters of four rootstock genotypes on germination, seedling vigour and production time of grafted cashew plants.

MATERIALS AND METHODS

Study site

The CNRA Fruit Research Station, located in Lataha, is 22 kilometres from the town of Korhogo. It covers an area of 40 ha, and is located between 9°34' North Latitude and 5°34' West Longitude. The station is at an altitude of 350 meters. It is under Sudanese type climate influence characterized by two seasons: dry season from November to April and rainy season from May to October. The average rainfall is 1400 mm in a wet year and 1000 mm in a dry year (Djaha et al., 2012).

Material

Plant material

The plant material used to conduct the experiment, was cashew nuts, rootstocks, scions and grafted cashew plants. Rootstocks were seedlings derived from the germination of seeds of four cashew genotypes, differing from each other in the size of their nuts. These are the followings: A43 (large), TESK2 (upper medium), A2SINE (medium) and PK23 (small). The grafts, woody vegetative branches of grey-green colour, were taken from the woodlot of the Lataha Research Station on high-producing cashew trees of genotype LAX3264 whose main characteristics are as follows (1) Yield/tree = 18 kg; (2) Graininess = 134 nuts / kg.

Methods

Selection of nuts

The nuts used in the trial were from A43, TESK2, A2SINE and PK23 genotypes, classified in descending order of nut size.

For each genotype, 50 nuts were selected from 1 kg batch by visual sorting according to the following criteria: well filled, ash-grey in colour, with no defects. Nuts with wounds and all types of abnormalities were eliminated.

Determination of nut morphometric parameters

The determination of the different morphometric parameters of nuts was done using IBPGR descriptor (1986). This is a manual that is referred to when determining the architecture of the plant, the morphology of its different organs (leaves, flowers, nuts and apple) and the dimensions of the latter.

The nuts used to determine the morphometric parameters for each genotype were taken at random from the 50 obtained. Twenty nuts per genotype were weighed using an electronic precision balance. The average weight was obtained by dividing the weight of the twenty nuts by their number. Length, width

and thickness were determined on ten nuts using a calliper.

Flotation test and dipping performing

The purpose of the flotation test, which is a type of sorting, is to identify nuts that are likely to have a high germination capacity. For this purpose, 50 nuts of each genotype were immersed for 30 minutes in a bucket containing 20 litres of water, in order to separate the floating seeds from the immersed ones, which are assumed to have a good germination capacity.

Soaking aims to stimulate the germination capacity of the nuts. It was carried out following the flotation test. The nuts were placed in the bucket of water and left there for 48 hours.

Germination tray preparation

The germination tray, which was used to conduct the experiment, is a cement installation 1.25 m wide, 0.50 m high and 10 m long. It contains a substrate of free soil, sand and manure in 1/2, 1/4 and 1/4 proportion. The soil in the germination tray was turned over with a hoe and then levelled with a rake. Subsequently, 3 cm deep furrows were made in the substrate to place the seeds.

Filling the nursery pots

The pots used for cashew nursery were solid black polyethylene bags with a few holes to drain off excess water at watering time. They were 25 cm long and 13 cm wide when flat. The bags, filled with potting soil, were placed under the greenhouse where the plants were grown.

Sowing

The surface of the germination tray was subdivided into four blocks of perpendicular length to the tray. Each block was then divided into four elementary plots, making a total of 16 plots for the whole trial. Five furrows were made in each elementary plot. Ten nuts were sown per elementary plot, i.e., 160 for the whole trial. After sowing, the seeds were covered with straw to protect them from incident solar radiations. Watering was then carried out. The seeds were maintained by regular watering twice a day, outside the hot hours of the day, until the nuts germinated.

Transplanting

When the nuts were found to be germinating, the germinated seeds were removed from the wet substrate. They were placed in a container lined with a piece of moistened jute sacking, to be transported to the breeding shed for transplanting into the pots. After transplanting, each pot was labelled with a number ranging from 1 to 160. This numbering provided all the information on each plant.

Phytosanitary maintenance of the plot

Two phytosanitary treatments were carried out. The first was carried out 15 days after transplanting (JAR). The product used was pyrical, an insecticide used to control insect pests that attack the leaves of young plants. For the treatment, one gram of product was applied to the potting soil per pot. The second treatment was carried out 68 days after transplanting (DAR). The products applied were callicuivre and callomil in a mixture. These were used to treat the young plants against rust and bacterial blight, which are diseases.

Assessment of cashew rootstock vigour

After emergence, measurements were taken on each plant for a fortnight to determine the vigour of the rootstocks. Measures were made on the diameter at the crown and the height of the stem. The formula used to assess the vigour of each rootstock was as follows Vigour = height (cm)/diameter (cm).

The vigour of the rootstocks was assessed by the ratio of height to diameter, because according to Alexandre (1977), the ratio of height to diameter is an index of the vigour of the above-ground and below-ground parts of the plant.

Grafting of cashew seedlings in the nursery

Semi-woody, hard, grey-green grafts were used to graft onto rootstocks that varied in age from 14 to 26 days after transplanting, probably because the rootstocks have different genetic characteristics.

Experimental design

The experimental design was a complete randomised block with four replications. The factor studied, the size of the

nut, was at four levels (large, upper medium, medium and small). The number of plants observed per elementary plot was 10, i.e., 160 plants for the four treatments and the four replications.

Post-grafting observations and measurements

Observations consisted of determined graft recovery time, time to maximum recovery and the corresponding rate of successful grafting, the duration of graft recovery, the rate of successful grafting and the duration of the period of production of grafted plants.

The scion is a portion of vegetative shoot 10-12 cm long and 0.5-1 cm in diameter, with a dormant apical bud. Recovery corresponds to the bud break of the graft, characterized by the appearance of leaf scales at the apex. Graft recovery time is the time interval between the date of grafting and the date of recovery of the first grafts. The maximum graft recovery time is the time interval between the date of grafting and the date when the maximum number of grafts has been recovered. The duration of the graft recovery is the time interval between the date of recovery of the first and last grafts. The duration of the graft production period is the number of days between the date of sowing of the rootstock seed and the date when the grafted plants are ready for transplanting in the field. All these time intervals are expressed in days. The grafting success rate was calculated by dividing the number of successful grafts by the number of grafted rootstocks multiplied by 100.

Data statistical analysis

The collected data were subjected to an analysis of variance (ANOVA) at the 5% significance level using GenStat Release 10.1 software. When the probability was greater than 0.05 ($P > 0.05$), no significant difference between the means was observed. On the other hand, when the probability was less than 0.05 ($P < 0.05$), significant difference between the means was observed. In this case means comparison test was performed. The least significant difference (LSD) method was used to separate the means.

RESULTS

Morphometric parameters of cashew nuts

Weight

The average nut weight was 13.40 g for the A43 genotype, 9.40 g for TESK2, 7.30 g for A2SINE and 6.05 for PK23. At least one highly significant difference was observed between the genotypes (Table 1).

Size (length and width)

The highest average length of 4.11 cm was recorded for genotype A43. In descending order there was TESK2 with 3.47 cm, A2SINE with 3.14 cm and PK23 with 2.82 cm. All these values were significantly different at the 5% level. The highest mean width of 2.23 cm was recorded for the genotypes A43 (large) and TESK2 (upper medium). For A2SINE (medium) and PK23 (small but medium according to Hammed et al. (2008)), the values recorded were 1.84 and 1.82 cm respectively. Statistical analysis did not reveal any significant difference between the latter two genotypes. However, a highly significant difference was recorded between the two pairs of genotypes (Table 1).

Nut thickness

The average nut thickness was 1.60 cm for genotype A43 (large) and 1.68 cm for TESK2 (large). No significant differences were recorded between these two genotypes (Table 1). The nuts of A2SINE (medium) and PK23 (small) had a thickness of 1.30 and 1.29 cm respectively, which were not significantly different (Table 1).

Effects of nut morphometric parameters on germination

Germination time and corresponding rate of germinated seeds

Germination started five days after sowing (DAS) with genotypes A43 (large), TESK2 (upper medium), A2SINE (medium) and eight days after sowing for PK23 (small). The average rate of germinated nuts at germination time ranged from 10 to 92.50%. At least one highly significant difference was found between the genotypes (Table 1).

Maximum germination time and corresponding germination rate of germinated seeds

The maximum number of nuts germinated between six and twelve days after sowing. The average rate of germinated nuts at the maximum germination time ranged from 20 to 92.50%. Statistical analysis revealed at least one highly significant difference between genotypes characterised by nut size. PK23 had a higher germination time than the other genotypes, which were not significantly different (Table 1).

Germination rate and duration of seed germination period

The germination rate ranged from 87.50 to 100% and no significant differences were observed between the genotypes. The average time interval between the beginning and the end of seed germination, or duration of the germination period, of the different genotypes varied between five and eight days. There was at least one significant difference between the genotypes at the 5% level. Indeed, the germination period of PK23 was shorter than that of other genotypes, which were not significantly different (Table 1).

Effect of morphometric parameters on rootstock age at grafting and rootstock vigour

Rootstocks from seeds of the genotypes A43 (large), TESK2 (upper medium) and A2SINE (medium), whose morphometric parameters were described in Table 2, were grafted 14 days after transplanting. On the contrary, the rootstocks from the germination of small seeds (genotype PK23) were grafted 26 days after transplanting. At least one highly significant difference was observed between the genotypes characterised by their nut size (Table 2).

Rootstock vigour, expressed as the ratio of stem height to diameter at the crown, ranged from 19.24 to 27.75. Statistical analysis revealed at least one significant difference between genotypes at the 5% level. Rootstock plants of genotype PK23 were more vigorous than the others, which were not significantly different (Table 2).

Effect of nut morphometric parameters on the duration of the production period of grafted plants

Graft recovery and unpacking time

The grafts recovered within 14.45 to 15.83 days after grafting (JAGREF). Unpacking time ranged from 22.7 to 26 DAGREF. No significant differences at the 5% level were observed between genotypes for these two parameters (Table 2).

Grafting success rate and production time of the grafted cashew plant

The grafting success rate was 67.50% for A43, 77.50% for TESK2 and A2SINE and 72.5% for PK23. The duration of the production period of the grafted plant varied between 68.62 and 73.17 days. Statistical analyses revealed no significant differences between genotypes at the 5% level for these two parameters (Table 2).

Table 1: Morphometric and germline parameters of nuts of different genotypes.

Parameter	Genotype				Probability
	A43	TESK2	A2SINE	PK23	
Weight (g)	**13.40 a**	**9.40 b**	**7.30 c**	**6.05 d**	**P < 0.001**
Length (cm)	4.11 a	3.47 b	3.14 c	2.82 d	P < 0.001
Width (cm)	2.23 a	2.23 a	1.84 b	1.82 b	P < 0.001

Thickness (cm)	1.60 a	1.68 a	1.30 b	1.29 b	P < 0.001
Germination time (JAS)	5 a	5 a	5 a	8 b	P < 0.001
Corresponding rate of sprouted nuts (%)	10.00 a	20.00 b	92.50 c	17.50 b	P < 0.001
Maximum germination time (JAS)	6.00 a	5.00 a	5.00 a	12.00 b	P < 0.001
Corresponding rate of sprouted nuts (%)	22.50 a	20.00 a	92.50 c	55.00 b	P < 0.001
Germination rate (%)	90.00 a	87.50 a	100.00 a	92.50 a	P > 0.05
Germination period duration (JAS)	8.00 a	8.00 a	7.00 a	5.00 b	P < 0.05

Table 2: Morphometric characteristics of nuts and grafting parameters of different genotypes.

Parameter	**Genotype**				**Probability**
	A43	**TESK2**	**A2SINE**	**PK23**	
Weight (g)	13.40 a	9.40 b	7.30 c	6.05 d	P < 0.001
Length (cm)	4.11 a	3.47 b	3.14 c	2.82 d	P < 0.001
Width (cm)	2.23 a	2.23 a	1.84 b	1.82 b	P < 0.001
Thickness (cm)	1.60 a	1.68 a	1.30 b	1.29 b	P < 0.001
Age of rootstock at grafting (JAL)	14 a	14 a	14 a	26 b	P < 0.001
Height (cm)	11.25 a	11.74 a	14.31 b	9.12 c	P < 0.001
Diameter (cm)	0.50 a	0.48 a	0.62 a	0.47 a	P= 0.244
Plant vigour (Height/Diameter)	22.45 ac	24.82 ab	27.75 b	19.24 c	P= 0.014
Graft recovery time (JAGREF)	14.60 a	15.83 a	14.45 a	15.53 a	P= 0.896
Time to unpack the grafts (JAGREF)	22.70 a	26.00 a	24.20 a	24.60 a	P=0.793
Grafting success rate (%)	67.50 a	77.50 a	77.50 a	72.5 a	P=0.710
Duration of the production of a grafted plant (JAS)	68.62 a	72.92 a	72.83 a	73.17 a	P= 0.071

DISCUSSION

Cashew cultivation is mainly based on the selection of useful phenotypic and agronomic traits such as nut size and weight (Mneney et al., 2001). For morphometric traits such as nut length, width and thickness, low variability was observed between genotypes, while high variability was observed in nut weight of rootstock genotypes. These results are in agreement with those of Lacroix (2003) who showed little variation in nut length and width in a study conducted on cashew seeds in Benin. Nut weights ranging from 5 to 17 g are higher than those determined by Chabi et al. (2015) and O'Farrell et al. (2000).

Seed germination started from 5 to 8 days after planting. This delay in germination may be due to the fact that cashew seeds have a hard outer shell, which must first be cracked before water can penetrate it, to reach the kernel, the seat of the embryo. Our results are in agreement with those of Danthu et al. (2003), who showed that generally, high seed dormancy is due to the presence of water- and air-impermeable seed coats that can delay germination for several months or years.

The germination rate of 87.5%-100% was high, probably due to intrinsic characteristics of the varieties or the good conservation of the seeds. Our results are consistent with those of Touré et al. (2018), who showed that seed germination quality is a function of several factors including pre-treatment and intrinsic characteristics of the variety.

The values of the Height/Diameter ratio between 19.85 and 23.82 for the genotypes A43, TESK2, A2SINE, and PK23 are well below 80. These low values of the Height/Diameter ratio reflect a good vigour of the rootstocks obtained under the experimental conditions. These results are due to the fact that the rootstocks reached 14 days after emergence (DAE) for some and 26 days (DAE) for others.

According to Frieden et al. (2004), young cashew trees less than two months old are at a period in the development cycle when height growth is not favoured over diameter growth. Our results are in agreement with those of Djaha et al. (2010) who obtained a Height/Diameter ratio less than 80 by studying the germination behaviour of two rootstocks.

Grafting times were short, and grafting success rates were quite good. No significant differences were observed between genotypes. This could be due to the fact that grafting was carried out in a favourable season. Our results are in agreement with those of Tokoré et al. (2017) who found that rainy season allows for a better recovery rate of the grafts. The results are also consistent with those of Ondo et al. (2018) and Narina et al. (2020) who showed that the success rate of grafting is influenced by several parameters including the month in which grafting is carried. Another reason could be a good adhesion between the cambiums of the rootstock and the graft, a good compatibility between the graft and the rootstock. Our findings corroborate those of Poëssel et al. (2000) according to which graft-rootstock combinations are often limited by graft incompatibility. The grafting success rates obtained in this work (67.50% for A43, 77.50% for TESK2 and A2SINE and 72.5% for PK23.) are similar to those recorded by Touré et al. (2017) who achieved a graft success rate of 66,66% using old scions and apical graft method. This is because the rootstocks were grafted at a very young age, between 14 and 26 days after emergence instead of the usual 30 days after emergence. At this age, the plants must be handled with care.

The unpacking times of the scions carried by the different rootstocks were not significantly different. However, they were higher than those obtained by Djaha et al. (2012). The production period of the grafted plants, on average 72 days after sowing, was short. This could be explained by the fact that the rootstocks were grafted young, 14 days after emergence for the first three and 26 days after emergence for the fourth, as opposed to at least 30 days after emergence normally. These values were lower than those obtained by Djaha et al. (2012) who produced grafted plants in six months.

Conclusion

At the end of the work, it was found that for the length, width and thickness of the nut, no significant difference was observed between the genotypes. On the contrary, for nut weight, a strong variability was observed within the rootstock genotypes.

Seed germination, which started at 5-8 days after planting, was generally short. However, seed germination time of the PK23 genotype, with the smallest nuts, was long.

In general, genotypes A43, TESK2, A2SINE, and PK23 had low values of Height/Diameter ratio reflecting good rootstock vigour. The time interval between the sowing date of the rootstock seeds and the date at which the grafted plants were suitable for transplanting was between 68 and 72 days, whereas 10 years earlier, at the CNRA, the plants were produced between 120 and 180 days. Morphometric parameters did not fundamentally affect the germination rate and the length of the production period of grafted plants. It would be desirable for nurserymen to use small to medium nuts with a higher seed count (number of nuts/kg) than large nuts. This will enable them to produce a larger number of rootstocks than with large nuts.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHOR'S CONTRIBUTIONS

JBAD is the experimental designer and editor of the manuscript. OYA contributed to the supervision of the data collection. AKYCL helped with the translation. CKK and LF made corrections to the manuscript.

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