EJSIT
European Journal of Science, Innovation and Technology
ISSN: 2786-4936
www.ejsit-journal.com
Volume 4 | Number 3 | 2024

Response of the Cashew Tree (*Anacardium occidentale* L.) to Pruning in Northeast Benin

Aboudou Djalidou Salifou and Arcadius Yves Justin Akossou*
Unit of Applied Statistics and Informatics (USIA), Laboratory of Studies and Research in Forestry (LERF), Department of Management of Natural Resources, Doctoral School of Agricultural and Water Sciences, University of Parakou, BP 123, Parakou, Benin

ABSTRACT

Efficiency management of the canopy architecture of fruit trees such as cashew (*Anacardium occidentale* L.) is important to increase their productivity. In this study, the effects of branch position and pruning intensity on vegetative and fruit-bearing growth of cashew tree were investigated. In this context, the design of complete randomization with three replicates of two factors (i) pruning severity (removal of 3 growth units (GUs), removal of 6 GUs and removal of 9 GUs), and (ii) branch position (Position A: pruning carried out at the apical part of the canopy, Position B: pruning carried out at the basal part of the canopy, and Position M: pruning from the middle) was used. A total of 12 trees was randomly sampled in an orchard of one hectare. On each tree, 15 axes were pruned randomly, with five axes per branch position. One of the three pruning severity modalities was applied to each position and alternated on the other positions in subsequent replications. Biomass and new budburst appearance were measured weekly, and parameters related to flowering and fruiting were collected. The results indicated that pruning promotes vegetative growth of cashew trees, increases the number and intensity of bud bursts and influences the morphology of the daughter GUs produced. Although the best budburst rates were obtained with lower severity, this trend was reversed over time with the biomass produced. The best productions were obtained with the removal of 9 GUs at the level of the basitone and acrotone branches. Apical GUs produced more than lateral GUs. Unlike the biomass produced, the best results on flowering and fruiting were obtained with moderate severity at the top of the tree. This study improves the understanding of the cashew tree's response to pruning, revealing the intricate relationship between branch position, pruning intensity and vegetative growth. This information is necessary for optimizing the growth and yield of the cashew tree through the practice of pruning.

Keywords: pruning, vegetative growth, growth unit, *Anacardium occidentale*, Benin

INTRODUCTION

The cashew tree (*Anacardium occidentale* L.) is a native of tropical America from Mexico to Peru and Brazil and of the West Indies as well [1], and it has become naturalized in coastal areas of many tropical countries [2]. It was introduced in the West African coasts around the 15th century as an ornamental plant and for fixing dunes. Nowadays, it is a booming cash crop after cotton and represents an opportunity for Africa through the export of its nuts [3, 4, 5]. Thus, between the years 2011 and 2018, raw cashew nut production in Africa increased from 1 million tons to 1.8 million tons with an annual growth of 5.8%, half of which was produced by Ivory Coast [6]. Its presence in Benin dates back to the 17th century and the organization of production began in the 1960s [7]. Cashew is one of the most exported agricultural products in Benin Republic with high economic value beside cotton. For instance, from 36,487 tons of raw nuts in 2001, Benin total exports reached 140,000 tons in 2018 [8]. As for the areas of cashew plantations, they increased from 10,000 hectares to 190,000 hectares

* Corresponding Author

between the years 1990 and 2010 [9, 10]. In 2015, the cashew tree became the second export product and the third pillar of the Benin economy. Recently, cashew is ranked second in terms of export earnings in Benin [11], with production and cultivated area estimated in 2021 at 150,414 tons and 406,893 ha [12]. With these trends, the Republic of Benin has been classified among the top ten world cashew producers with 2% of world production [13]. Development of the cashew value chains improves income generation and significantly increases the local and national economy [14, 15]. Although Benin has shown increasing cashew nut production over the years and has favorable and productive land for cashew tree cultivation, several constraints constitute a limitation to its full expansion. Hence, the productivity of cashew orchards in Benin remains relatively low. Indeed, while countries like India, Tanzania, Brazil and Vietnam have cashew nut production per tree varying between 10 kg and 15 kg [16], cashew nut production per tree in Benin, is around 5 kg [17]. In addition, cashew nut yields from existing plantations have gradually declined over recent cropping years [10, 14]. Obviously, the improvement of cashew nut production observed in Benin Republic may be due to the increase in the cultivated area because of the establishment of new plantations.

Improving fruit tree productivity in general and that of cashew in particular, requires the use of good crop management practices (plant material, sowing method, planting density, trellising, arching, pruning, etc.) [18, 19, 20]. Hence, various studies have been carried out to understand the biotic and abiotic factors, as well as agronomic practices that determine the productivity of the cashew tree, and suggested solutions to improve the performance of cashew plantations [10, 14, 21, 22, 23, 24]. Among these practices, there is pruning, which is a cultural operation, carried out with the aim of improving the performance of the pruned tree in terms of efficiency of light interception, vegetative and fruit-bearing growth [25, 26, 27]. Pruning is an important orchard management that helps to obtain the desired tree shape, to get rid of infected branches and to obtain a better yield of fruit [22, 28, 29, 30]. However, according to other authors, fruit tree pruning can also lead to yield reduction that may be caused by the decrease of the leaf area, the reduction in the number of branches that could bear fruit and the loss of elaborate serf contained in the removed axes [31]. Decreasing yields are generally observed the following year after pruning [32, 33, 34, 35]. It has been shown that such reduction in yield is proportional to the intensity of pruning [36], and quality of the pruning operation may also affect the quality of the fruits [37]. In Benin, cashew tree pruning is used by many farmers. However, implementation of this agricultural operation in cashew farms does not follow any recommendation and uniformity based on scientific evidence. This may partly explain the low productivity level of cashew plantations in Benin Republic. Studies on pruning of fruit trees and its effects on the physiology and productivity of the trees were conducted in temperate regions. Knowledge on the responses of tropical trees, especially cashew to pruning are lacking. Indeed, cashew is a fast-growing woody perennial tree and if allowed to grow naturally the canopy will be in irregular shape with low spreading branches. Orchards with such trees are difficult to manage and will result in poor nut yield. Therefore cashew plants should be meticulously pruned and trained from the beginning of their orchard life so as to derive higher benefits from the trees in later years [38].

Moreover, previous studies on fruit tree pruning have mainly focused on variation in yields between pruned and unpruned trees, without analyzing pruning effect on the vegetative growth of fruit trees [37], specifically for cashew plantations. Furthermore, studies carried out on the pruning of fruit trees have shown that pruning leads to a loss of biomass that the trees tend to reproduce by stimulating vegetative growth [39, 40, 41]. This vegetative growth can influence flowering and fruiting downstream [42]. It is clearly appeared that a better understanding of the effect of pruning on yield necessarily requires a better understanding of the effect of pruning on vegetative growth not only on the tree but also on some organs of the plant like growth unit (GU).

This study aimed at analyzing the effects of different pruning methods on the vegetative growth and yield of cashew trees in order to identify pruning strategies that optimize cashew tree growth and productivity.

MATERIALS AND METHODS

Study Area

The study was conducted in the municipality of N'Dali in the Northeast of Benin (9° 51′ 39″ North, 2° 43′ 05″ East) (**Figure 1**). The area has a Sudano-Guinean type of climate and characterized by a long rainy season from April to October follow by a long dry season from November to March. The annual rainfall varies between 900 and 1,300 mm per year. The average annual temperature is around 26°C with a maximum of 32°C in March and drops to around 23°C in December-January. The relative humidity varies between 30 and 7.

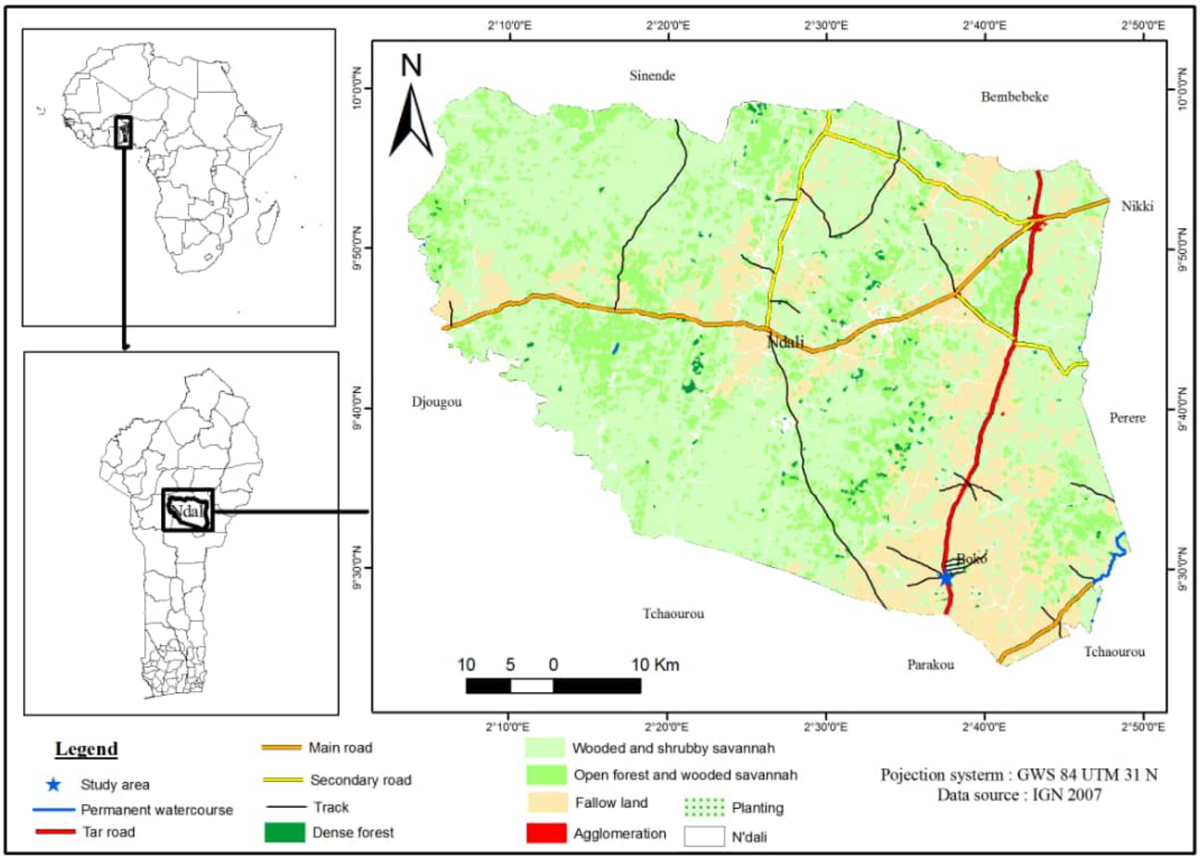

Figure 1: Localization of the study area

Experimental Design

The study was carried out between January and April 2021 in a cashew plantation established in 2011, with a spacing of 10 m x 10 m. The plantation has been well maintained and has never been fertilized. The last pruning operation in the orchard was in 2019, meaning that the observed trees had not been pruned for the last two years before the experiment was carried out, such a spare time is enough to avoid any potential long-term effect of the previous pruning.

In Benin, the harvesting of cashew fruits starts from January and ends in April or May. Pruning is carried out after the harvest between the months of May and July [9, 43]. Vegetative recovery is characterized by the development of new growth units (GU) also known as "daughter GU". GU represents the portions of the additional axes that have developed over an uninterrupted period [44]. The effect of pruning was evaluated on the growth of the plant axes of order three, i.e. on the branches that bear flowers and fruits. Two factors were considered: (i) the position of the branch at the level of the canopy and (ii) the severity of the pruning, which was defined as the depth of pruning along the axis. For the position, three levels were defined. The height of the canopy was measured and then divided into three equal parts (**Figure 2**), leading to the three pruning positions: Position A: apical part of the canopy, Position B: basal part of the canopy, and Position M: middle part of the canopy. In practice, each part corresponds to a branch position on the tree for physical delimitation. Position B represented the branches located completely at the base of the canopy, that is, the basitone branches. Position M represented the branches located in the middle and stands for the mesotonic branches. Finally, position A represented the branches located at the top of the tree (acrotonic branches). In other words, the three levels of the factor pruning position were: (i) position B: where pruning was done on the basitone branches, (ii) position M: where pruning was carried out on the mesotonic branches, and (iii) position A: where pruning was done on the acrotonic branches. Similarly, for the factor pruning severity, three levels were defined: (i) S1: removal of 3 GUs, (ii) S2: removal of 6 GUs, and (iii) S3: removal of 9 GUs.

Three trees were randomly selected, on which pruning severity was applied to for each pruning position. For each position, five branches (specifically axis of order 3) were chosen randomly. One of the three severity modalities (TS1, TS2 and TS3) was applied to the five branches of each position. The treatment was repeated four times. Giving a total of 12 trees, randomly distributed in the one-hectare plantation. For the whole experiment, 3 x 3 x 5 x 4 = 180 branches were pruned.

Pruning was done by counting from the terminal GU along the axis to the number of GU to be removed (3, 6 or 9 GUs according to the level of severity to be applied). The cut was made at the junction between the N^{th} GU to be removed and the $(N+1)^{th}$ GU along the axis. For example, to remove 3 GUs, the cut was made at the junction of the third GU and the fourth GU along the axis (**Figure 3**). In order to better understand the effect of pruning on the GUs, 12 other GUs including 6 lateral GUs and 6 apical GUs which had not undergone pruning were randomly sampled around the pruned GUs of each tree and marked at the beginning of the experiment. The unpruned GUs observed come either from the same branch (axis of order 3) of the pruned GU, or from the axis of order 2 from which the branch of the pruned GU comes from.

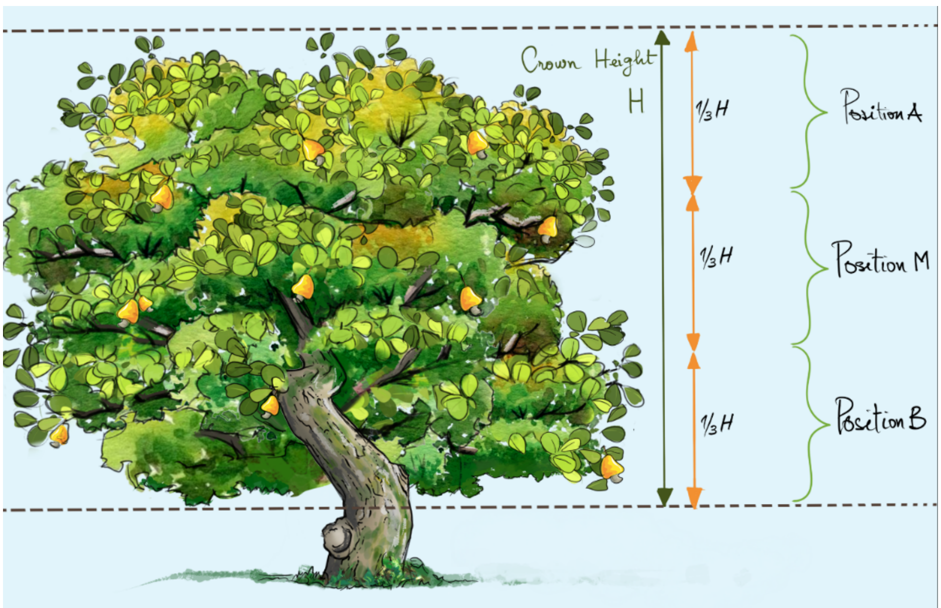

Figure 2: Description of the different pruned positions .on the cashew tree

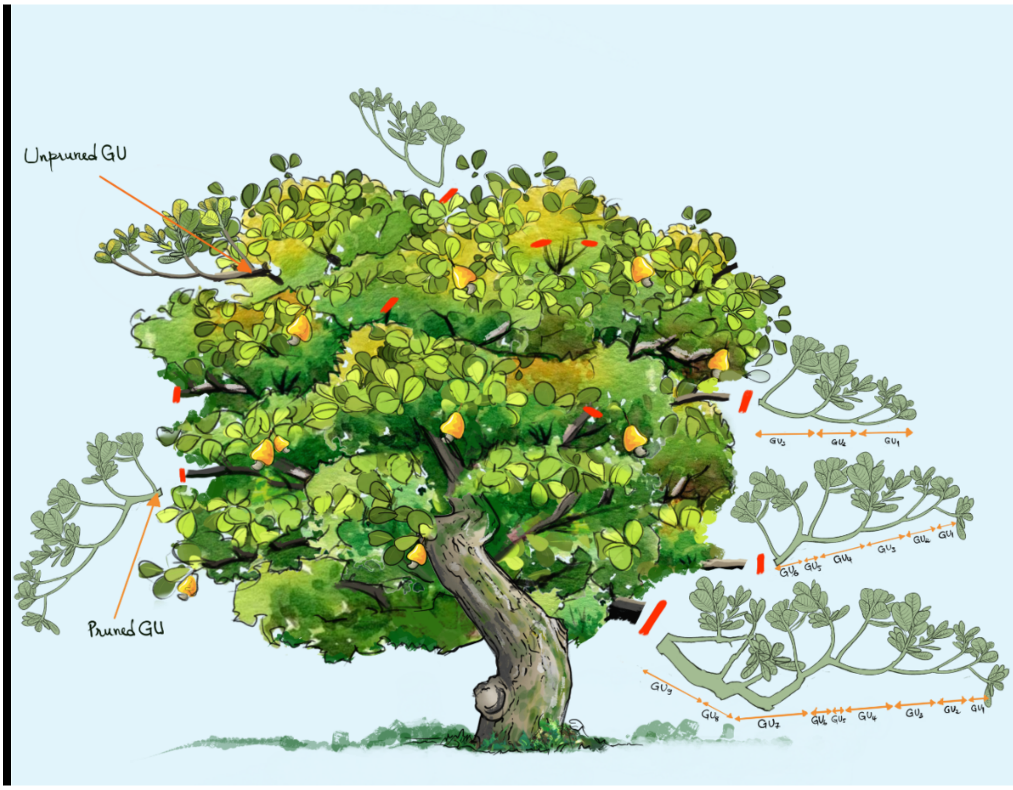

Figure 3: Description of the removal of Growth Units

Data Collected

Vegetative growth between pruned and unpruned branches was monitored based on the characteristics of the GUs. The diameter at the cut point of each GU was measured using calipers. The fresh biomass removed from the tree per treatment was weighed. Leaf area (cm²) of each removed branches was estimated from the section of the GU at the cutting point using the allometric relationship for cashew in Benin (**Equation 1**) as determined by Akossou et al. [45].

$$S^{0.032} = 0.033\ln(Ll) + 0.996 \text{ (where } S\text{= area, } L \text{ = length, } l \text{ = width of the leaf)} \quad (1)$$

Growth and development data were collected weekly in the plantation during the vegetative growth period to monitor the recovery of the trees after pruning. The number of new GUs (daughter GUs) produced at the level of pruned and unpruned GUs was collected. Axis length, number of leaves, maximum length and width of the middle leaf were recorded for each daughter GU. The surface area of each middle leaf was estimated using **Equation 1**. The leaf area (LA_{GU}) of each daughter GU was estimated as the product of leaf number ($nLeaf$) and middle leaf area (LA_{MID}) (**Equation 2**). The total leaf area (LA_{TOT}) produced by a pruned or unpruned GU corresponds to the sum of the leaf areas of each daughter GU (**Equation 3**).

$$LA_{GU} = nLeaf\ x\ LA_{MID} \quad (2)$$

$$LA_{TOT} = \sum LA_{GU} \quad (3)$$

At flowering, the number of inflorescences on the daughter GU, the number of lobes, the number of male flowers, the number of hermaphroditic flowers and the number of sterile flowers on the inflorescence carried by the GU daughter were counted.

Finally, at fruiting, the number of nuts and the quantity obtained on the axis carrying the GU were collected.

Data Analysis

Vegetative growth was described by three variables: (1) the occurrence of budburst, (2) the intensity of budburst and (3) the leaf area produced by the monitored GU.

The occurrence of budburst was defined as a binary variable that can take two values: 1 if there was budburst and 0 otherwise. The GUs budburst rate of a given severity level or modality corresponds to the number of GUs having budburst out of the total number of GUs monitored for modality. Budburst intensity was described through the number of daughters GUs produced by the GU, which can take values between 1 and n (n being a natural number). The leaf area produced by the GU corresponds to the sum of the leaf areas of each daughter GU.

Analyzes were performed with R software (version 4.3.0). The effects of pruned position, pruning severity, and their two-way interactions (explanatory variables) were analyzed using generalized linear models (GLM) on the following response variables: (i) budburst occurrence, (ii) bud break intensity, (ii) morphology of daughter growth units (GUs), (iii) flowering parameters of daughter growth units (GUs) and fruiting parameters of growth units (GUs). For counted data, the Poisson error distribution was used, except where overdispersion was observed. In the latter case, the Poisson distribution was replaced by the quasi-Poisson distribution. The GLM analyzes were followed by a deviance analysis with the Chi2 test. GLMs were based on the maximum likelihood method. When a significant effect of a factor was observed, a mean comparison test was carried out using the Tukey method.

RESULT

Data Description

The key attributes of pruned branches categorized by their respective positions within the canopy and the severity of the pruning were presented in **Table 1**. The provides characteristics encompassed, the circumference of cut point, the amount of biomass removed, the count of leaves, and the average dimensions of the leaves in terms of length and width. The mean of cutting circumference values ranged from 5.57 to 12.02 cm, depending on the position and severity of pruning. The biomass removed from pruned branches increased with intensity of pruning severity and ranging an average from 0.52 to 3.82 kg. The number of mean leaf showed variations, ranging from 132 to 654 leaves, was also influenced by pruning position and severity. An average, the lengths of the leaves of pruned branches remain closed across different position and severities. The widths of the leaves of pruned branches showed limited variation, with values between 7.33 and 7.48 cm.

Characteristics of unpruned branches according their position in the canopy and the nature of the growth unit (**Table 2)** showed that the values varied in the same orders of magnitude for a given characteristic. However, there was an average variability within the values of each characteristic. The cutting circumferences varied on average from 1.57 to 2.22 cm, depending on position. The number of pruned GUs near unpruned GUs varied, with a range of 1 to 2. The number of GUs separating pruned and unpruned GUs varied on average from 7 to 9.

Table 1: Characteristics descriptive of pruned branches by position and severity

Variables	Parameters	Position								
		A			B			M		
		Severity			Severity			Severity		
		TS1	TS2	TS3	TS1	TS2	TS3	TS1	TS2	TS3
Cutting circumference (cm)	Mean	5.57 (0.22)	8.39 (0.43)	12.02 (0.55)	5.95 (0.27)	8.95 (0.49)	11.70 (0.53)	5.82 (0.18)	9.08 (0.49)	10.53 (0.46)
	Min	4.00	5.00	8.00	4.00	5.50	8.00	5.00	5.50	8.00
	Max	7.30	12.00	15.20	8.00	14.50	15.00	7.30	15.00	14.50
	CV	17.96	23.09	20.60	20.20	24.72	20.40	13.87	23.93	19.52
Biomass (kg)	Mean	0.52 (0.06)	1.86 (0.16)	3.82 (0.29)	0.63 (0.09)	2.09 (0.26)	3.54 (0.28)	0.68 (0.14)	2.27 (0.2)	3.01 (0.29)
	Min	0.00	1.00	1.75	0.20	0.78	1.40	0.27	0.90	1.00
	Max	1.25	3.20	6.10	1.30	5.00	5.40	3.00	4.30	5.50
	CV	55.5	38.42	33.45	63.96	55.94	35.62	89.22	39.41	43.18
Number of leaves	Mean	132 (13)	341 (19)	654 (56)	179 (23)	398 (43)	577 (60)	143 (11)	369 (38)	559 (72)
	Min	2	210	283	1.9	150	268	84	132	175
	Max	267	500	1350	394	814	1350	255	705	1554
	CV	42.70	24.86	38.27	56.28	47.68	46.09	34.21	45.53	57.60
Length (cm)	Mean	15.9 (0.58)	16.05 (0.63)	16.28 (0.64)	16.13 (0.55)	16.63 (0.64)	16.18 (0.54)	16.00 (0.58)	16.35 (0.57)	16.00 (0.6)
	Min	12.00	12.00	12.00	12.50	12.00	12.00	12.00	12.00	12.00
	Max	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
	CV	16.44	17.44	17.70	15.19	17.26	14.99	16.35	15.66	16.84
Width (cm)	Mean	7.33 (0.15)	7.48 (0.19)	7.43 (0.25)	7.25 (0.2)	7.43 (0.18)	7.4 (0.16)	7.43 (0.24)	7.38 (0.23)	7.25 (0.18)
	Min	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
	Max	8.50	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
	CV	8.93	11.38	14.86	12.36	10.98	9.71	14.70	13.89	11.08

Table 2: Characteristics descriptive of unpruned branches by position and nature of the growth unit

Variables	Parameters	Position					
		A		B		M	
		Nature of growth unit		Nature of growth unit		Nature of growth unit	
		Apical	Lateral	Apical	Lateral	Apical	Lateral
Apical circumference (cm)	Mean	1.95 (0.17)	2.12 (0.15)	2.22 (0.22)	1.57 (0.14)	1.72 (0.15)	2.16 (0.18)
	Minimum	0.80	1.00	0.70	0.75	0.70	0.70
	Maximum	4.00	3.00	5.00	2.70	3.00	3.60
	Variation coefficient	41.61	34.54	48.80	44.65	41.39	39.74
Number of pruned GU	Mean	1.33 (0.14)	1.80 (0.34)	1.21 (0.10)	1.46 (0.13)	1.80 (0.35)	1.55 (0.26)

	Minimum	1.00	1.00	0.00	1.00	1.00	1.00
	Maximum	3.00	7.00	2.00	3.00	7.00	7.00
	Variation coefficient	52.65	93.07	42.12	45.12	95.94	83.33
Number of GU between GU pruned and GU unpruned	Mean	8.38 (1.10)	9.75 (0.88)	8.21 (0.91)	7.50 (0.78)	7.08 (0.82)	8.71 (0.88)
	Minimum	0.00	5.00	0.00	0.00	0.00	0.00
	Maximum	24.00	24.00	22.00	15.00	15.00	22.00
	Variation coefficient	64.33	44.37	54.36	50.96	56.61	49.59

Bud Burst of the Growth Unit Observed

During the study period, the percentage of GUs which have budded was high for most monitored GUs (**Figure 4**). It varied from 75.76 to 100% and depended on the severity whatever the position ($\chi^2 = 14.08, p = 0.01$; $\chi^2 = 16.93, p = 0.00$ and $\chi^2 = 14.16, p = 0.01$ respectively at position B, M and A). The highest values (100%) were observed for GUs pruned with severity S1 (TS1) and unpruned apical GUs (NTA) regardless of the position, while the lowest value (75.76%) was observed at the level of the GU pruned with severity S3 (TS3) at position M. In the case of the unpruned GUs, the lateral unpruned GUs mostly showed the lowest values. In addition, it was observed that when the rate of bud burst decreased the severity of pruning increased, particularly at the level of position A (acrotonic branches) and M (mesotonic branches).

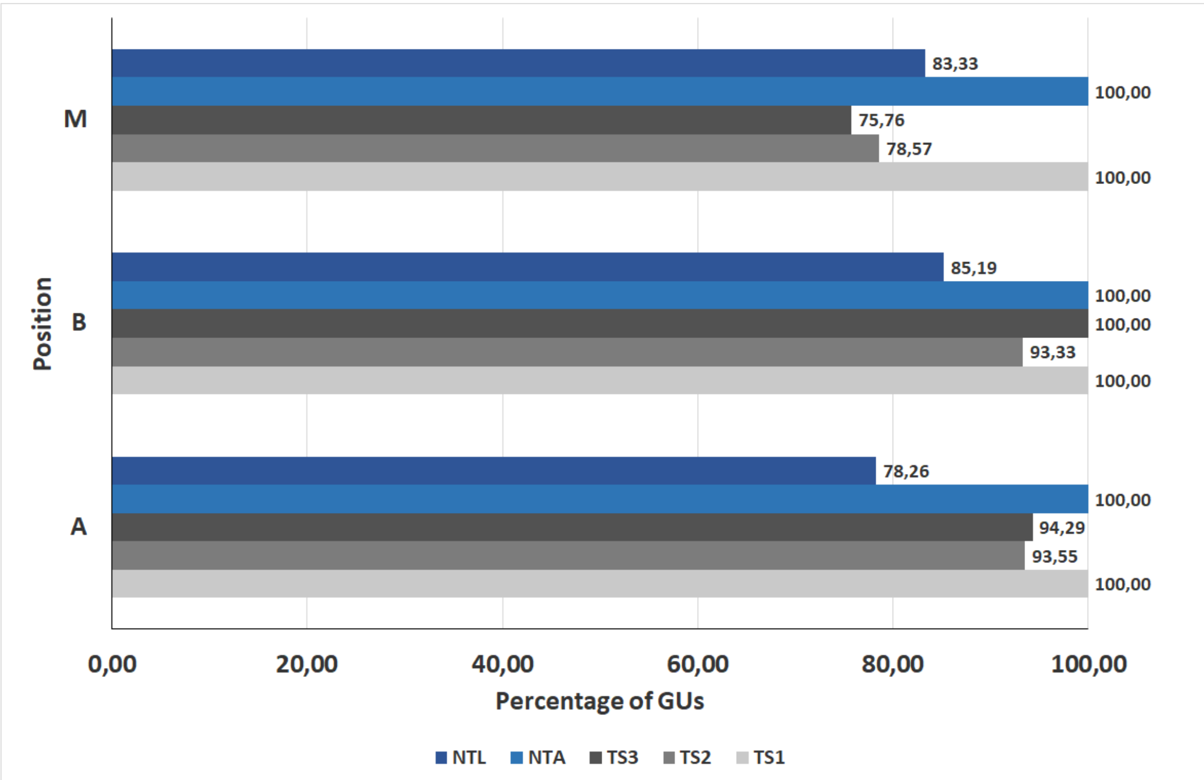

Figure 4: Budburst rate of pruned and unpruned GUs for different severity at each position. (NTL = unpruned lateral GU, NTA = unpruned apical GU, TS1 = S1 severity pruned GU, TS2 = S2 severity pruned GU, TS3 = S3 severity pruned GU)

Bud Break Intensity

Analysis of budburst intensity described by the number of daughter GUs produced by the GU showed that there was no interaction between position and severity (Chi²=5.46, p = 0.60). Comparison of the severities for each position and that of the positions for each severity (**Table 3**) showed that the S1 severity (TS1) produced more daughter GUs. The number of daughter GUs produced was estimated at 3 when pruning was carried out at the level of the basitone branches (position B). This number decreased to 2 daughter GU for the pruning of the acrotonic branches (position A) and 1 at the level of the mesotonic branches (position M).

Table 3: Comparison of bud break intensity of different severity at each position

Position	Severity				
	TS1	TS2	TS3	NTA	NTL
B	2.8^{Aa}	1.4^{BCa}	$2.0A^{Ba}$	1.4^{BCa}	1.0^{Ca}
M	1.4^{Ab}	1.1^{Aa}	1.2^{Aa}	1.2^{Aa}	0.8^{Aa}
A	1.7^{Ab}	$1.4A^{Ba}$	1.5^{ABa}	1.3^{ABa}	0.8^{Ba}

The means in the columns denoted by different lowercase letters show significant difference between positions at the 5% level and the means in the columns denoted by different capital letters show significant difference between severities at the 5% level. (NTL = unpruned lateral GU, NTA = unpruned apical GU, TS1 = S1 severity pruned GU, TS2 = S2 severity pruned GU, TS3 = S3 severity pruned GU)

Biomass Produced

Results on biomass production (length of daughter GU axis, daughter GU leaf width and length, and the total leaf area by GU) showed the existence of an interaction between position and severity. The resulting multiple comparison of means (**Table 5**) revealed that the effects were different depending on the position and the level of pruning severity. For the daughter GU length axis produced, there was no difference between the severities at position B. Similarly, at position M, there was no difference among the severities in the total leaf area produced. Overall, pruned GUs produced more biomass than unpruned GUs. The greatest biomass productions were obtained with severity S3 (TS3), which corresponded to the removal of 9 GUs at the level of the basitone and acrotone branches (positions B and A). Thus, the highest value of the axis length of the daughter GU was estimated at 25.6 cm and was obtained in position A with severity S2. However, this value was not different from that obtained at position B with severity S3, i.e. 21.9 cm. The highest values of average leaf width and length of daughter GU were 8.3 cm and 17.5 cm, respectively. They were obtained at position B with severity S3. Finally, which of the total leaf surface produced by the GU was estimated at 3 303 cm² and was also obtained at position B with severity S3.

The means in the columns of **Table 5** denoted by different lowercase letters show significant difference between positions at the 5% level and the means in the columns denoted by different capital letters show significant difference between severities at the 5% level. (NTL = unpruned lateral GU, NTA = unpruned apical GU, TS1 = S1 severity pruned GU, TS2 = S2 severity pruned GU, TS3 = S3 severity pruned GU).

Table 5: Comparison of the severities for each position and that of the positions for each severity for daughter GU axis length (in cm), width (in cm) of daughter GU leaf, length (in cm) of daughter GU leaf and the total leaf area produced by the GU (in cm²)

Variable	Position	Severity				
		TS1	TS2	TS3	NTA	NTL
Length of the axis (branch) of the daughter GU (cm)	B	15.7^{Aa}	17.6^{Ab}	21.9^{Aa}	18.2^{Aa}	16.8^{Aa}
	M	18.7^{Aa}	16.5^{ABb}	9.4^{Bb}	17.7^{ABa}	15.1^{ABa}
	A	17.5Ba	25.6^{Aa}	17.1^{Ba}	20.0^{ABa}	14.2^{Ba}
Daughter GU leaf width (cm)	B	7.0^{Ba}	6.9^{ABa}	8.3^{Aa}	7.0^{ABa}	6.6^{Ba}
	M	7.1^{Aa}	7.1^{Aa}	5.5^{Ab}	7.3^{Aa}	6.1^{Aa}
	A	7.5^{ABa}	7.2^{ABa}	7.8^{Aa}	7.5^{ABa}	5.8^{Ba}
Daughter GU leaf length (cm)	B	15.4^{ABa}	14.8^{ABa}	17.5^{Aa}	15.4^{ABa}	14.1^{Ba}
	M	15.5^{Aa}	14.8^{Aa}	11.9^{Ab}	15.8^{Aa}	13.1^{Aa}
	A	16.1^{ABa}	15.5^{ABa}	16.5^{Aa}	16.1^{ABa}	12.6^{Ba}
Total leaf area produced by the GU (cm²)	B	3002.2^{ABa}	1701.9^{BCa}	3303.1^{Aa}	1291.9^{Ca}	1088.0^{Ca}
	M	1678.5^{Ab}	1534.7^{Aa}	1154.7^{Ab}	1295.2^{Aa}	906.4^{Aa}
	A	2011.0^{ABab}	2212.8^{Aa}	2680.6^{Aa}	1755.4^{ABa}	932.8^{Ba}

Flowering and Fruiting

Flower production by the daughter GU depended on the severity whatever the position ($\chi^2 = 20.49, p = 0.00$; $\chi^2 = 35.35, p = 0.00$ and $\chi^2 = 20.49, p = 0.00$ respectively at position B, M and A) (**Figure 5**). The highest values (100%) were observed at the level of the apical unpruned GUs (NTA) whatever the position considered. They were followed by GUs pruning with severity S1 (TS1), except those relating to position M, whose value was the lowest at this position. The GUs pruning with the severity S3 (TS3) presented the lowest values.

Overall, the TS1 severity presented the highest values both in terms of parameters relating to flowering and fruiting. It is followed by the unpruned NTA. The values observed at the apical GUs were higher than those of the lateral GUs except those of severity TS3. The values relating to the different flowering and fruiting parameters decrease depending on the intensity of the severity, except the number of sterile flowers counted on the inflorescence carried by the daughter GU. The number of inflorescences counted on the daughter GU was practically identical for all combinations of modalities considered, and was estimated at one inflorescence per daughter GU. The number of lobes, the number of male flowers and the number of hermaphrodite flowers counted on the inflorescence carried by the daughter GU decrease with the intensity of the severity. The highest value of the number of lobes was estimated at 8 lobes per inflorescence and was obtained with severity TS1 at position A. Those of the number of male flowers and the number of hermaphrodite flowers were respectively estimated at 52 male flowers and 11 hermaphrodite flowers per inflorescence and were obtained also with severity TS1 at position A. On the other hand, the number of sterile flowers counted on the inflorescence carried by the daughter GU was lower with severity TS1 at position A and higher with severity TS3. Fruiting parameters (the number and quantity of nuts obtained on the axis carrying the GU) also decrease with severity intensity. The highest values were obtained with severity TS1 at position A and were estimated at 372 seeds and 1.7 kg per axis of growth unit (GU), respectively.

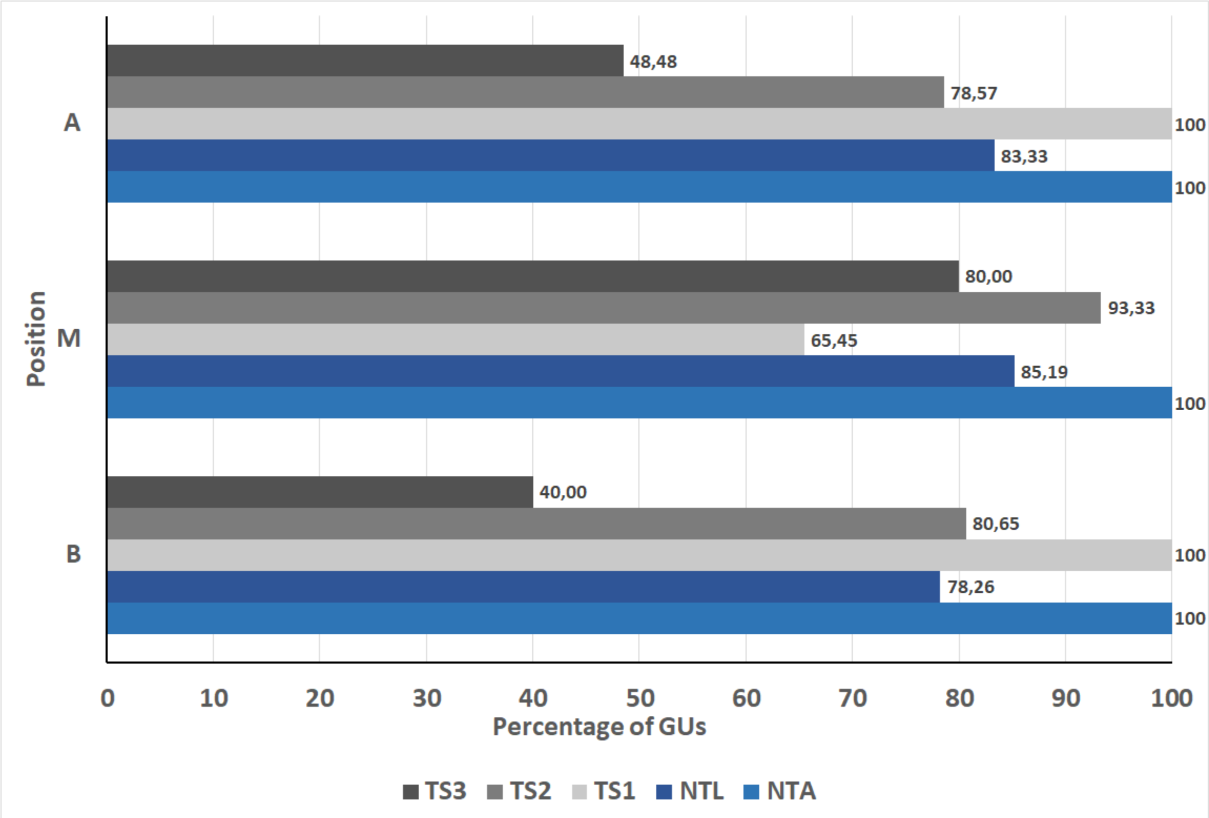

Figure 5: Percentage of daughter growth unit that produced flowers according to position and severity. (NTL = unpruned lateral GU, NTA = unpruned apical GU, TS1 = S1 severity pruned GU, TS2 = S2 severity pruned GU, TS3 = S3 severity pruned GU)

Table 6: Effect of branch position and severity on flowering and fruiting parameters: Multiple comparison of means

Variable	Position	Severity				
		TS1	TS2	TS3	NTA	NTL
Number of Inflorescences counted on the daughter GU	B	0.6^{Bb}	0.9^{Aa}	0.8^{Aa}	1.0^{Aa}	0.8^{Aa}
	M	1.0^{Aa}	0.8^{Aa}	0.5^{Bb}	1.0^{Aa}	0.8^{Aa}
	A	1.0^{Aa}	0.8^{Aa}	0.4^{Bb}	1.0^{Aa}	0.8^{Aa}
Number of lobes counted on the inflorescence carried by the daughter GU	B	3.6^{Cb}	7.4^{Aa}	3.8^{Ca}	6.0^{Aa}	5.0^{Ba}
	M	7.3^{Aa}	4.5^{BCb}	3.0^{Cab}	6.7^{Aa}	5.6^{ABa}
	A	8.2^{Aa}	4.6^{Bb}	2.1^{Cb}	6.1^{Ba}	4.2^{Ba}
Number of male flowers counted on the inflorescence carried by the daughter GU	B	20.1^{Cc}	47.5^{Aa}	21.8^{Ca}	35.1^{Ba}	29.0^{Ba}
	M	42.9^{Ab}	23.9^{BCb}	16.8^{Cab}	40.4^{Aa}	32.5^{ABa}
	A	52.2^{Aa}	29.4^{Bb}	11.7^{Cb}	35.1^{Ba}	25.6^{Ba}
Number of Hermaphrodite flowers counted on the inflorescence carried by the daughter GU	B	3.3^{Cc}	10.2^{Aa}	3.8^{Ca}	5.9^{Ba}	4.9^{Ba}
	M	6.9^{Ab}	3.6^{BCb}	2.7^{Cab}	6.7^{Aa}	5.4^{ABa}
	A	11.4^{Aa}	4.6^{Bb}	2.0^{Cb}	6.1^{Ba}	4.2^{BCa}
Number of Sterile flowers counted on the inflorescence carried by the daughter GU	B	0.7^{Ba}	0.1^{Bb}	0.7^{Bab}	1.3^{Aa}	0.4^{Ba}
	M	0.3^{ABa}	$0.5A^{Ba}$	0.8^{Aa}	0.9^{Aa}	0.2^{Ba}
	A	0.3^{Ba}	0.5^{ABa}	0.2^{Bb}	0.9^{Aa}	0.2^{Ba}

Number of nuts obtained on the axis carrying the GU	B	229.4^{ABb}	256.8^{Aa}	173.5^{Ba}	194.3^{ABb}	194.0^{ABa}
	M	149.6^{BCc}	151.8^{BCb}	119.9^{Cb}	233.6^{Aab}	208.1^{ABa}
	A	372.4^{Aa}	247.0^{BCa}	179.1^{Ca}	306.9^{ABa}	261.1^{ABCa}
Quantity of nuts obtained on the axis carrying the GU (kg)	B	1.1^{Ab}	1.0^{Aa}	0.6^{Bb}	0.6^{Bb}	0.6^{Bb}
	M	0.5^{Bc}	0.5^{BCb}	0.4^{Cc}	0.7^{Ab}	0.7^{Aab}
	A	1.7^{Aa}	0.9^{Ba}	0.8^{Ba}	1.0^{Ba}	0.8^{Ba}

DISCUSSION

The productivity of fruit trees depends on several factors, but, management of canopy architecture being the most important [46]. Being a tree crop of significant commercial importance, the productive performance of cashew is greatly influenced by how best its canopy is architecture for harnessing maximum benefits in terms of yield [47]. The initial formation of the leaf is therefore crucial for the development of photosynthetically efficient canopy in cashew trees as well as in other perennial fruit trees [47]. In the present study, the effect of branch position and pruning severity on biomass production, flowering and fruiting were investigated. The bud burst rate was as high on the pruned GUs as on the unpruned GUs (75.76 to 100%). This result showed that the cashew tree has a good ability to regenerate its biomass. Indeed, the cashew is a vigorous evergreen perennial woody plant having long juvenility and high heterozygosity [47] even if the varieties which are available nowadays are semi vigorous to vigorous type. Additionally, canopy development in cashew is a seasonal and continuous process.

Vegetative Growth

Buds are important for the vegetative and reproductive growth of trees. Management of fruit trees includes to some extent trees pruning activity that mainly involves the manipulation of buds. The best results for buburst intensity (increased number of bud burst) were obtained with low severity (removal of 3 GUs) at the basitone (position B). This could be explained by the fact that the branches pruned under this combination of modality were older, more numerous and have probably benefited more from the effects of solar radiation. Indeed, the size of the branches, implicitly the age of the branches, is a determining factor in the appearance of buds. The first branches formed on the tree being the branches located at the base (position B), these are larger than those which will be formed later in position M or A. Therefore, they have a greater chance of producing buds. Moreover, light is important and essential for the growth and development of fruit trees and implicitly for fruit production. The green leaves assimilate the sunlight to produce carbohydrates and sugars which are transported to the different parts of the tree where they are required for development of inflorescence, buds, flowers, and fruits [47]. Trends observed for the severity factor in this study were contrary to those reported on mango tree (*Mangifera indica*), in particular on the cultivars Cogshall [26, 48], Amrapali, Mallika and Dashehari [49] and on blueberries [50]. These contrary results resided probably in the branches chosen for the study. Indeed, in cashew canopy development, two type branching exists, in which one is intensive and the other is extensive [51]. In high yielding trees more than 60 per cent intensive branches are seen whereas low yielders possess less than 20 per cent intensive branches [47]. Results from Kovaleski et al. [50], revealed that high levels (removal of 60% of canopy) of pruned trees increased the number of lateral branches, which may change hormonal activities in blueberries. The authors also showed that apical meristem, as a resource sink, plays a significant role in shifting basal meristem towards development of new shoots, floral growth, and many others development processes. Another study, bearing on the effect of tree pruning severity of two apple tree varieties, highlighted the effect of pruning at a distance of unpruned branches, with an increase in the number of daughter

GUs and the axis length in the case of high pruning severity compared to unpruned trees [41]. The effect of the distance was not emphasized in the present work, because the distances considered in terms of number of GUs were practically of the same order of magnitude (8 GUs separating the pruning GU and the unpruned GU). The maximum daughter GU length value of 26 cm obtained with S2 severity (removal of 6 GUs) at the acrotonic position (position A) showed that the chosen branches can be considered as extensive type. According to Adiga et al. [47], the "intensive shoot" grows to a length of about 25-30 cm and ends in a panicle, while in the "extensive type", the shoot grows to 20-30 cm length and rests. Compared to unpruned GUs, particularly the lateral GUs, pruned GUs exhibited globally, the highest values for budburst intensity. These results can be explained by the fact that pruning suppresses apical dominance [52]. The suppression of apical dominance influences the cytokinin: auxin ratio [53], thereby increasing development of new buds [54].

Biomass production for trees growth and development, in terms of the length of the axis of the daughter GU, the width and length of the leaves of the daughter GU and the total leaf area produced by the GU, increased with the intensity of the pruning. The highest values observed for these growth and development parameters were obtained by the removal of 9 GUs at the level of the basitone and acrotone branches (positions B and A). This could be partly explained by a positive effect of pruning intensity or pruning severity on vegetative growth, but not on bud burst development. The structure of the canopy could also be another reason. Indeed, canopy architecture is determined by the number, length and orientation of the stem, branches and shoots [47]. Moreover, the areas of the tree leaves located in the South of the plantation were the largest and had the highest quantities of dry mass [45]. Similar results were found in other species such as mango (*Mangifera Indica*). Thus, the axis length of daughter GUs increased with pruning severity for several *Mangifera Indica* cultivars, like *Tommy Atkins*, *Keitt*, *Amrapali*, *Mallika*, *Dashehari*, *Cogshall* [26, 39, 49, 55]. These observations were also revealed in the mandarin tree (*Citrus reticulata Blanco*) [56]. Overall, results from this study showed that pruning is beneficial for cashew tree growth. However, pruning should be done in moderation. Indeed, as the results showed heavy pruning promotes excessive vegetative growth and often reduces the yield due to the large and dense canopy which in turn, negatively influence the flowering processes [57]. Nevertheless, the response to pruning depends on age, growth habits, tree vigor, varieties, location, and cultivation practices of cashew [58].

Flowering and Fruiting Response

Overall, pruning positively affected growth and yield. Unlike the results relating to biomass production, the best results for the effect of severity on flowering and fruiting were obtained with moderate pruning (severity TS1). As for position, the best results were observed at the top of the tree (position A). The severity TS3, on the other hand, gives the lowest values whatever the position. However, the response to pruning of young trees had varied effects depending on the different varieties of cashew trees [38]. The growth in terms of number of flowering, length of the shoots, flowering intensity, number of leaves per shoot and leaf area was positively affected by pruning in most of the cashew varieties pruned. Generally, pruning on cashew varieties with extensive branching type of cashew varieties induces more number of leaves and thereby increased leaf area while in the intensive branching types even without pruning more the number of shoots arose during flushing period [38]. The differences between pruned and unpruned trees can be explained by the fact that pruning increases the number of new shoots of the current season on which appear cashew flowers [59]. These results corroborate those of Murali [38] who demonstrated that pruning cashew trees combined with foliar fertilizer spraying significantly increases inflorescences per square meter. Moreover, reducing aboveground biomass during pruning increases plant productivity and light absorption [47]. However, pruning should be practiced in moderation as shown by the results of the present study. In addition, the results showed that the number of hermaphroditic flowers obtained on the pruned UGs was practically double that of the unpruned UGs. Thus, pruning significantly increases the proportion of bisexual flowers [38]. Furthermore, this increase in bisexual flowers led to an increase in yield, expressed here in terms of number and quantity of nuts produced by the axis carrying the UG. In fact, it has long been known that the proportion of bisexual flowers increases cashew nut output [60]. The increased exposure to light from the canopy is what is causing the hermaphroditic flower rate to rise [61].

The best results were observed at the top of the tree (position A). In an experiment carried out on several varieties, Nayak [38] noted that on an average only about 10 percent light was found to penetrate through the canopy and reach the ground. Of the remaining bout 69-94 per cent of the incidental light was found be intercepted in the top portion of the canopy, 0-16 per cent by mid portion and remaining 3-15 percent light by lower branches. The top portion of the pruned trees intercepts more light because of the higher number of shoots and leaf area compared to unpruned trees. According to the same author, the light interception was maximum in the top portion of the canopy due to intensive branching induced by pruning on the top exposed canopy surface and a small portion of light only penetrates to the interior portion. As a result more fruiting was seen on the top portion of the canopy. However, Nayak [38] noted over several years for the four varieties, that the mean yield of these cashew varieties estimated at bottom (low), middle and top portion of the pruned and unpruned plants canopy revealed that middle portion yielded more than 49.50 percent of yield and top portion about 32.9 percent and the lower portion around 17.5 percent. This contrary result could be explained by the fact that the response to pruning depends on many factors. Thus, canopy management must take into account the specificity of each context and must be considered an ‘art’ of fruit growing. It is much more than cutting off a few branches [47].

CONCLUSION

This study provides a better understanding of the vegetative and yield responses of the cashew tree to pruning in terms of structure (burst rate, bud break intensity, biomass produced, flowering and fruiting). The result showed that pruning increases vegetative growth, by affecting the rate and intensity of bud burst, the morphology of the daughter GUs produced, flowering and fruiting at the level of the GUs. Unlike the biomass produced, the best rates of budburst, flowering and fruiting were obtained with low severity. Pruning intensity, position of pruned branches and type of growth unit had a positive effect on growth and yield. Lateral GUs producing weak buds must be removed from the branches when pruning. Moderate pruning carried out at the level of the apical branches at all positions allows the growth and yield of the tree to be optimized. Overall, this study provides valuable information on the complex relationship between pruning strategies and vegetative responses of cashew trees. It lays the foundations for informed decisions to optimize yield and biomass production. However, for a generalization of the results, it is important to take into account other growing conditions of the species in time and space. It is also important to analyze the effect of these pruning strategies on the quality of the fruits produced, particularly nuts.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

S.A.D. carried out the work, collected the data and wrote the manuscript. A.Y.J.A. corrected the protocol, verified the data collection forms, supervised the processing and analysis of results, and drafted the manuscript. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The authors are grateful the Republic of Benin through the Ministry of Higher Education and Scientific Research, which has supported our research through the Doctoral Support Program (PAD).

REFERENCES

[1] N. Kumar, V. Ponnuswami, S. Jeeva, C. Ravindran, D. Kalaivanan, Cashew industry in India – An overview. Chronica Hortic. 52(1), (2012) 27–33.

[2] IBPGR, Genetic Resources of Tropical and Sub-Tropical Fruits and Nuts (Excluding Musa). Rome. International Board for Plant Genetic Resources (1986), https://pdf.usaid.gov/pdf_docs/PNAAW619.pdf, (Accessed December 11, 2023).

[3] E. Dedehou, J. Dossou, M. Soumanou, Diagnostic study of cashew apple processing technologies into juice in Benin. Int. J. Biol. Chem. Sci., 9(1), 371 (2015), https://doi.org/10.4314/ijbcs.v9i1.32.

[4] P.L. Soro, N. Touré, F.M.T. Koné, M.K. Kouadio, K.M. Djè, S. Dabonné, Optimization of the Physical Stabilization of Coconut Milk Using Cashew Gum (*Anacardium occidentale* L.) as a Stabilizing Agent. Eur. Sci. J. 17(7), 227 (2021), https://doi.org/10.19044/esj.2021.v17n7p227.

[5] D. Seydou, Y. Alpha Seydou, K. Laya, D. Ali, Influence of Intercropping and Border Crops of Guinea Sorrel and Okra on the Dynamics of Insect Pests and Cotton Production in the Agro-ecological Conditions of Katibougou, 2019 / Mali. Eur. Sci. J. 18(8), 214 (2022), https://doi.org/10.19044/esj.2022.v18n8p214.

[6] S. Hien, Overview of the evolution of cashew production and the evolution of the raw cashew nut market in the sub-region and prospects for 2019/2020. Sahelian cashew forum. From August 5 to 7, 2019 in Bamako (Mali), (2019), https://www.africancashewalliance.com/sites/default/files/2_focas_2019_sansan_nkalo_marche_et_production_fr.pdf, (Accessed January 18, 2024).

[7] P. Lemaître, P. Bediye, H. Ahouari, Global diagnosis of the cashew sector in Benin. Project to improve and diversify operating systems – PADSE, (2003), https://hubrural.org/IMG/pdf/benin_diagnostic_filiere_anacarde_padse.pdf, (Accessed December 18, 2023).

[8] P. Ricau, The West African cashew Sector in 2018. General trends and country profiles. Analysis of cashew production, processing and trade in West Africa. Nitidæ, landscapes and value chains, (2019), https://www.nitidae.org/files/41dc7432/wa_cashew_sector_review_2019_nitidae.pdf, (Accessed December 18, 2023).

[9] A.M. Tandjiekpon, Analysis of the Value Chain of the Cashew Sector in Benin. African Cashew Initiative (ICA), (2010), https://africancashewinitiative.com/files/files/downloads/aci_benin_frz_150.pdf, (Accessed December 18, 2023).

[10] D.O. Bello, L.E. Ahoton, A. Saidu, I.P.B. Akponikpe, V.A. Ezin, I. Balogoun, NI. Aho, Climate change and cashew (*Anacardium occidentale* L.) productivity in Benin (West Africa): Perceptions and endogenous measures of adaptation. Int. J. Biol. Chem. Sci., 11(3), (2017) 924-946, https://doi.org/10.4314/ijbcs.v11i3.1.

[11] I. Balogoun, Characterization of edaphic and climatic factors for improving cashew productivity in Benin, Doctoral Thesis in Agricultural Sciences, University of Abomey-Calavi, Benin, (2016).

[12] FAOSTAT, Statistics Division of the Food and Agriculture Organization of the United Nations, Rome Italy, (2023),

https://www.fao.org/faostat/fr/#search/production%20mondiale%20noix%20d'anacarde, (Accessed January 18, 2024).
[13] M. Gogohounga, I.A. Labiyi, A.G. Coami, Y.E. Miassi, N. Ollabode, J.A. Yabi, Characterization of forms of contractualization in the cashew sector in the Collines department of Benin. Agron. Afr. 31(2), (2019) 173–186.
[14] I. Balogoun, A. Saïdou, E.L. Ahoton, L.G. Amadji, C.B. Ahohuendo, I.B. Adebo, S. Babatounde, D. Chougourou, H. Adoukonou-Sagbadja, Characterization of cashew-based production systems in the main growing areas in Benin. Agron. Afr. 26(1), (2014) 9-22.
[15] B. Sali, C. Madou, A. Nome, J. Kuate, Socio-economic characterization of large cashew production areas (*Anacardium occidentale* L.) and behavioral study of their population in northern Cameroon. Int. J. Biol. Chem. Sci., 14(6), (2020) 2094–2111, https://doi.org/10.4314/ijbcs.v14i6.13.
[16] P.A.L. Masawe, Consultancy Report on Cashew Improvement Programme for Selected West African Countries (Benin, Burkina and Côte d'Ivoire), GIZ/iCA, Accra, (2010).
[17] DSA, Evolution of cashew production from 2018 to 2021, (2021), https://dsa.agriculture.gouv.bj/statistics/vegetale, (Accessed January 18, 2024).
[18] P. Lauri, F. Laurens, Architectural types in apple (*Malus xdomestica* Borkh.). In: Ramdane Dris (eds.), Crops: growth, quality and biotechnology, World Food Limited, Helsinki, Finland, (2005), 1300–1314.
[19] M. Orlando, Agro climatology of cashew production in Guinea-Bissau. Master's degree in agronomy, Regional Center AGRHYMET (2007), https://www.memoireonline.com/04/15/9051/m_Agroclimatologie-de-la-production-de-l-anacardier-en-guinee-bissau21.html, (Accessed December 6, 2023).
[20] K. Diulyale, S.B. André, T. Yaya, K. Tchoa, S. Nakpalo, R. Noémie, K. Daouda, K. Mongomaké, Evaluation of the overgrafting technique for the renewal of aging cashew orchards (*Anacardium occidentale* L.) in the Gontougo region in Ivory Coast. Eur. Sci. J. 15(6). (2019), https://doi.org/10.19044/esj.2019.v15n6p304.
[21] N. Zoumarou Wallis, M.A. Bagnan, A.Y.J. Akossou, C.B. Kanlindogbé, Morphological characterization of a collection of cashew fruits from the commune of Parakou (Benin). Int. J. Biol. Chem. Sci. 10(6) (2016) 2413-2422. http://dx.doi.org/10.4314/ijbcs.v10i6.1
[22] O. Olubode, T. Joseph-Adekunle, L. Hammed, A. Olaiya, Evaluation of production practices and yield enhancing techniques on productivity of cashew (*Anacardium occidentale* L.) Evaluation of production practices and yield enhancing techniques on productivity of cashew (*Anacardium occidenta*le L.). Fruits, 73, (2018), https://doi.org/10.17660/th2018/73.2.1.
[23] J.T. Yaméogo, R.Y.S. Ouattara, B. Tankoano, M. Hien, P. Ouoba, Flora, structure and health status of woody populations in agroforestry parks in the forests of Dindéresso and Kuinima in western Burkina Faso. Eur. Sci. J. 16(40), 48 (2020), https://doi.org/10.19044/esj.2020.v16n40p48.
[24] A.D. Salifou, G. Babatounde, A.Y.J. Akossou, Effect of sowing method and color of cashew accessions (*Anacardium occidentale* L.) on nut yield in North-Eastern Benin. Eur. Sci. J. 18(24), 149 (2022), https://doi.org/10.19044/esj.2022.v18n24p149.
[25] M. Karkee, B. Adhikari, S. Amatya, Q. Zhang, Identification of pruning branches in tall spindle apple trees for automated pruning. Comput. Electron. Agr. 103, (2014) 127–135. https://doi.org/10.1016/j.compag.2014.02.013.
[26] S. Persello, I. Grechi, F. Boudon, F. Normand, Nature abhors a vacuum: Deciphering the vegetative reaction of the mango tree to pruning. Eur. J. Agron., 104, (2019) 85–96. https://doi.org/10.1016/j.eja.2019.01.007.

[27] E.S. du Toit, J. Sithole, J. Vorster, Pruning intensity influences growth, flower and fruit development of Moringa oleifera Lam. Under sub-optimal growing conditions in Gauteng, South Africa. S. Afr. J. Bot. 129, (2020) 448–456. https://doi.org/10.1016/j.sajb.2019.11.033.

[28] B. Dendena, S. Corsi, Cashew, from seed to market: A review. Agron. Sustain. Dev. 34(4), (2014) 753–772. https://doi.org/10.1007/s13593-014-0240-7.

[29] W.V. Tarpaga, L. Bourgou, M. Guira, A. Rouamba, Agro morphological characterization of cashew trees (*Anacardium occidentale* L.) in selection for high yield and superior quality of raw nuts in Burkina Faso. Int. J. Biol. Chem. Sci., 14, (2020) 3188–3199. https://dx.doi.org/10.4314/ijbcs.v14i9.17.

[30] S.H. Azam-Ali, E.C. Judge, Small-scale cashew nut processing, Schumacher Centre for Technology and Development, Bourton on Dunsmore, Rugby, Warwickshire, UK, 2001). http://www.fao.org/3/a-ac306e.pdf, (Accessed January 18, 2024).

[31] S.A. Oosthuyse, G. Jacobs, Flowering synchronization of 'sensation' mango trees by winter pruning. Acta Hortic. 455, (1997) 422–430. https://doi.org/10.17660/ActaHortic.1997.455.54.

[32] A.P. Preston, Pruning experiments with pears. J. Hortic. Sci. 48(2), (1973) 195–201, https://doi.org/10.1080/00221589.1973.11514521.

[33] R.P. Marini, Physiology of pruning fruit trees. Virginia Cooperative Extension Publication 422-025 (2003), Blacksburg, Virginia, USA, https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/422/422-025/SPES-235.pdf, (Accessed December 8, 2023).

[34] S.J. Wertheim, Pruning. In: E.J. Tromp, A.D. Webster and S.J. Wertheim (eds.), Fundamentals of temperate zone tree fruit production, Backhuys Publishers, Leiden, The Netherlands, (2005) 176–189.

[35] R. Asrey, V.B. Patel, K. Barman, R.K. Pal, Pruning affects fruit yield and postharvest quality in mango (Mangifera indica L.) cv. Amrapali. Fruits 68, (2013) 367–380, https://doi.org/10.1051/fruits/2013082.

[36] C. Forshey, D. Elfving, R. Stebbings, Training and pruning apple and pear trees. American Society for Horticultural Science (eds.), Alexandria, Virginia, USA, (1992).

[37] S. Persello, Response of the mango tree (Mangifera indica L.) to pruning: characterization and integration into a structure-function model of the effects of pruning on vegetative growth and reproduction. Thesis to obtain the degree of doctor from the University of Montpellier in Agricultural Sciences, (2018), https://theses.hal.science/tel-02063431/document, (Accessed December 18, 2023).

[38] K. Murali, P.P. Kumar, M.S.A. Rani, Effect of tertiary shoot pruning and foliar spray of nutrients on flowering and yield of cashew (*Anacardium Occidentale L.*) under high density planting system. The Biescan (10(1), 2015) 411-415.

[39] S. Oosthuyse, Pruning of Sensation mango trees to maintain their size and effect uniform and later flowering. South Afr. Grow. Assoc. Yearb. 14, (1994) 1-6, https://www.hortresearchsa.co.za/hort_research_sa/Books_and_Literature_files/Pruning%20of%20Sensation%20Mango%20Trees%20to%20Maintain%20Their%20Size.pdf, (Accessed December 18, 2023).

[40] K.J. Niklas, Modelling below- and above-ground biomass for non-woody and woody plants. Ann. Bot. 95, (2005) 315–321. https://doi.org/10.1093/aob/mci028.

[41] D. Fumey, P.-E. Lauri, Y. Guédon, C. Godin, E. Costes, How young trees cope with removal of whole or parts of shoots: An analysis of local and distant responses to pruning in 1-year-old apple (Malus × domestica ; Rosaceae) trees. Am. J. Bot. 98(11), (2011) 1737–1751. https://doi.org/10.3732/ajb.1000231.

[42] M. Capelli, P.-É. Lauri, F. Normand, Deciphering the costs of reproduction in Mango – vegetative growth matters. Front. Plant Sci. 7, 2016, https://doi.org/10.3389/fpls.2016.01531.
[43] E.J. Lacroix, Cashew trees, cashew nuts and the cashew sector in Bassila and Benin. Bassila forest resources restoration project, Bassila, (2003), https://hubrural.org/IMG/pdf/anacarde-benin-gtz.pdf, (Accessed November 28, 2023).
[44] F. Hallé, R.A. Oldeman, P.B. Tomlinson, Tropical trees and forests: An architectural analysis. Berlin, Germany, Springer Science & Business Media, (1978), https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers20-09/09318.pdf, (Accessed January 28, 2024).
[45] A.Y.J. Akossou, A.D. Salifou, L.A. Tchiwanou, S.A.A. Saliou, M.H. Azoua, Area and Dry Mass Estimation of Cashew (Anacardium occidentale) Leaves: Effect of Tree Position within a Plantation around Parakou, Benin. J. Exp. Agr. Int., 15(1) (2017) 1-12. https://doi.org/10.9734/JEAI/2017/29798.
[46] A.K. Goswami, A. Nagaraja, Jai Prakash, Madhubala Thakre, (2014), https://www.biotecharticles.com/Agriculture-Article/ Canopy- Management of Fruit Crops- 3199.html, (Accessed January 10, 2024).
[47] D.J. Adiga, G.L. Veena, V. Thondaiman, M. Babli, An overview of canopy management in cashew (Anacardium occidentale L.). J. Hortic. Sci., 15(2), (2020) 127–135. https://doi.org/10.24154/jhs.v15i2.905.
[48] A. Dezileaux, Study of the effect of cultural practices on the development of mango tree yield (End of study dissertation). Toulouse: Engineering School PURPAN (2017). https://cosaq.cirad.fr/content/download/4410/32656/version/1/file/Ecole+Ing%C3%A9nieur+3A_Dezileaux+2017.pdf, (Accessed January 18, 2023).
[49] G. Singh, Canopy Management in Fruit Crops, Practicle Manual. Department of Agriculture & Cooperation (eds.), Ministry of Agriculture, Govt. of India, New Delhi-110001 (2010).
[50] A.P. Kovaleski, J.G. Williamson, B. Casamali, R.L. Darnell, Effects of timing and intensity of summer pruning on vegetative traits of two southern high bush blueberry cultivars. Hort. Sci. 50, (2015) 68-73, https://doi.org/10.21273/HORTSCI.50.1.68.
[51] P.L. Saroj, M.G. Nayak, R.K. Meena, Physiology of flowering, fruit and nut development in cashew. In Souvenir, National Seminar-cum-Workshop on Physiology of Flowering in Perennial Fruit Crops, (eds.) H. Ravishankar, V.K. Singh, A.K. Misra, and M. Mishra, (2014) 105–114.
[52] N.Y. Amen, A. Alèdi, Response of Cashew (Anacardium occidentale L.) to Pruning Systems for Yield Attributes and Nut Quality in Tchamba District, Togo. Int. J. Plant Soil Sci., 34(24), (2022) 90-98. https://doi.org/10.9734/ijpss/2022/v34i242617.
[53] E.A. Dun, B.J. Ferguson, C.A. Beveridge, Apical dominance and shoot branching. Divergent opinions or divergent mechanisms? Plant Physiol. 142(3) (2006) 812-819. https://doi.org/10.1104/pp.106.086868.
[54] L. Rufato, L.D.R. Marchioretto, J.C. Orlandi, M.F. Michelon, A. De Rossi, G.F. Sander, T.A.D. Macedo, Lateral branch induction at nursery with growth regulators in 'Maxi Gala' apple trees grafted on four rootstocks. Sci. Hortic. 253, (2019) 349-357, https://doi.org/10.1016/j.scienta.2019.04.045.
[55] T. Yeshitela, P.J. Robbertse, P.J.C. Stassen, Effects of pruning on flowering, yield and fruit 1051 quality in mango (Mangifera indica). Aust. J. Exp. Agric. 45, (2005) 1325-1330, 1052 https://doi.org/10.1071/EA03185.
[56] A.T. Salem, G.M. Hasseb, H.M. Kamel, Effect of pruning severity on vegetative growth, flowering and fruit setting of Balady mandarin trees. Egypt. J. Appl. Sci. 23 (2008) 285-296.

[57] T.N. Balamohan, P. Mekala, S. Rajadurai, G. Priyadarshini, K. Prakash, K. Soorianathasundaram, N. Kumar, Canopy management in mango. TNAU Offset and Printing Press, Coimbatore (2016).
[58] J.D. Adiga, B.M. Muralidhara, P. Preethi, S. Savadi, Phenological growth stages of the cashew tree (*Anacardium occidentale* L.) according to the extended BBCH scale. Ann. Appl. Biol. 175(2): (2019) 246-252, https://doi.org/10.1111/AAB.12526.
[59] Adiga JD, Muralidhara BM, Preethi P, Savadi S. Phenological growth stages of the cashew tree (*Anacardium occidentale L.*) according to the extended BBCH scale. Ann. Appl. Biol. 2019;175: 246-252. DOI: 10.1111/aab.12526.
[60] Kumar DP, Udupa KS. The association; 1996. Accessed Dec. 14, 2022. Avalable: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Kumar%2C+D.P.+and+K.S.Udupa%2C+1996.+The+association+between+nut+yield+attributing+characters+in+cashew+%28Anacardium+occidentale+L.%29.+Cashew%2C+10%281%29%3A+11-17.&btnG.
[61] Waghmare G, Joshi G. Response of mango (*Magifera indica*) to light pruning for vegetative and flowering flushes; 2008. Accessed: Dec. 14, 2022 [Online]. Available: https://agris.fao.org/agris-search/search.do?recordID=IN2022003022.