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RESEARCH ARTICLE

Agronomic Performance of Young Cashew Trees Cultivated in Association with Groundnuts

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ABSTRACT

Cultural association is widely practiced in rural areas by cashew nut producers. These producers typically cultivate annual plants between the rows of young cashew trees. However, there are interactions between these associated crops, which can either result in complementarity or competition among the plants for environmental resources such as water and nutrients. Consequently, young cashew seedlings newly planted were associated with groundnuts during their first two years. The aim of this study was to investigate the compatibility of the cashew/groundnut system. The results showed that there is competition between groundnuts and young cashew trees in the first year, leading to poor cashew growth in association. Nevertheless, from the second year onwards, cashew trees cultivated in association exhibited similar growth to those cultivated in monoculture. Therefore, it would be advisable to plant groundnut seeds sufficiently far from cashew tree seedlings to avoid potential competition in the first year of cultivation.

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1. Introduction

Crop association is defined as the simultaneous cultivation of two or more plant species on the same surface for a significant period of their growth (Perrin & Lefevre, 2019). It is a widely practised farming system in tropical regions and is adopted by the majority of cashew nut producers worldwide (Adiga & Kalaivanan, 2017). These associations are typically established with food crops during the early stages of cashew tree growth (Konan & Ricau, 2010). According to Penot and Feintrenie (2014), this farming system enables farmers to generate substantial income through agricultural product diversification. Consequently, crop association appears to be a solution to the low incomes earned by farmers during the initial establishment and production phases of their orchards, as well as to the fluctuations in cashew nut yields and prices.

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However, the plants involved in these associations interact with each other. This interaction can result in either complementarity or competition between the crops. Practices that involve intercropping cashew trees with other crops may therefore carry risks such as competition for water, mineral elements, light, etc. Consequently, only a well-thought-out crop association that takes these risks into account and aims for a more efficient use of natural resources would be appropriate (Keli et al., 2005). According to Mansaray et al. (2022), the benefits of crop association are observed when the components of the system exhibit different morphological growth patterns and strongly compete for natural resources at different times. In the context of cashew farming, the recommended cropping system by Visalakshi et al. (2015) involves associating cashew trees with herbaceous plants, including legumes. The rationale behind intercropping cashew trees with legumes is based on the principle that trees can utilize the nitrogen fixed by the legume. In this relationship, the legume can either increase the available nitrogen content or compete with the non-fixing plant. However, non-leguminous plants typically do not benefit from associated legumes unless the non-fixing plants continue to absorb nitrogen after the senescence or death of the legumes (Mansaray et al., 2022).

Furthermore, in Côte d'Ivoire, the results of the survey conducted by Letto et al. (2022) have shown that groundnuts are the leguminous crop most commonly associated with cashew trees in the northern part of the country. However, the agronomic performance of cashew trees cultivated in association with this legume is not yet known. The present study was therefore conducted following this survey with the aim of investigating the growth and development of young cashew trees cultivated in monoculture and in association with groundnuts in northern Côte d'Ivoire.

2. Materials and Methods

2.1. Study Site

The present study was conducted at the research station of the National Centre for Agronomic Research (CNRA) in Ferkessédougou (longitude 5.22° W, latitude 9.59° N). This locality is the capital of the Tchologo region in the Savanes District, Northern Côte d'Ivoire (Figure 1). The soil at the site is of remodeled ferritic type, with a sandy-clayey texture, and is characterized by a moderate-depth lateritic induration (70-75 cm) (Akanza & N'Guessan, 2017). The soil has an acidic pH (6.45) and is poor in organic matter (Akanza & N'Da, 2018). The climate of the Tchologo region is of the Sudanese type, characterized by a dry season extending from November to April. The rainy season lasts from May to October, with the highest precipitation occurring in August. The Tchologo region has an average annual temperature of 26.4 °C and a rainfall of 1260 mm (Soro et al., 2020).

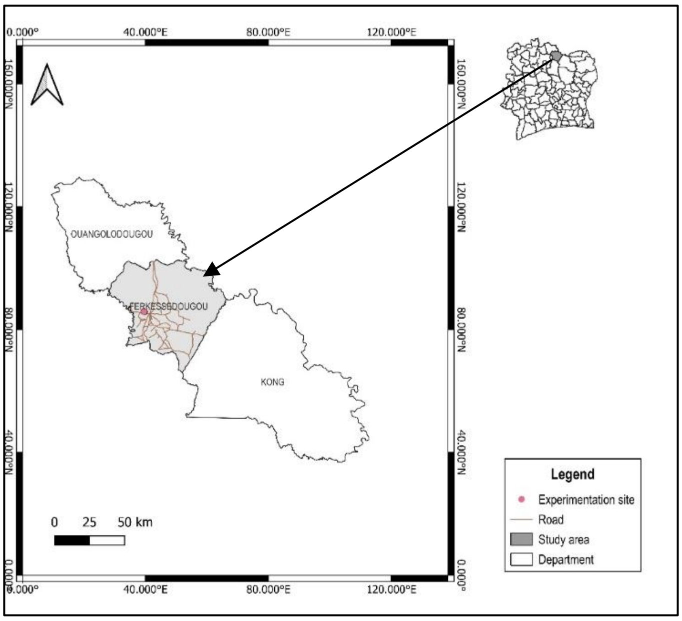

Figure 1. Study site.

2.2. Plant Material

The plant material used consisted of 45-day-old grafted cashew tree (*Anacardium occidentale* L.) seedlings. In addition, groundnut seeds commonly cultivated in rural areas of the Tchologo region, with a vegetative cycle of 120 days, were included.

2.3. Experimental Procedure

The effect of three levels of planting spacing on cashew tree growth was evaluated. The cashew trees were planted at three different spacing configurations: 10 m × 10 m, 12 m × 12 m, and 14 m × 14 m. As for groundnuts, they were sown between the rows of cashew trees, 7 days after the cashew tree planting. Groundnut seeds were sown in pairs (2 seeds per pocket), with a spacing of 0.50 m between rows and 0.20 m between pockets. Additionally, some cashew trees were grown in monoculture and served as control.

In this cashew tree and groundnut association, no mineral or organic fertilizers were applied throughout the two-year experimental period.

2.4. Experimental Design

The experimental design used was a split-plot with three replications. The main factor, cashew tree spacing, had three levels: 10 m × 10 m, 12 m × 12 m, and 14 m × 14 m. The secondary factor, the cropping system, had two levels: cashew tree monoculture and cashew tree/ groundnut association. With three levels of the main factor and two levels of the secondary factor, a total of six elementary plots were used per replication. Each elementary plot consisted of 12 cashew trees.

2.5. Parameters Studied

2.5.1. Mortality rate

The mortality rate of cashew trees was evaluated based on the cropping system employed. Dead cashew trees were counted on a weekly basis for two years. After counting the cashew trees, the mortality rate was calculated using the following formula:

$$MR = \frac{\text{number of dead cashew trees}}{\text{total number of cashew trees}} \times 100 \quad (1)$$

Where: MR = Mortality Rate.

2.5.2. Growth rate

The growth rate was used to assess the percentage of elongation of cashew trees compared to their initial state. Height and stem diameter at the collar were determined monthly for two years. Height was measured from the collar to the apex of the stem using a measuring tape. Collar diameter was measured at the base of the plants using a caliper. The growth rate was then calculated as follows:

$$GR = \frac{m1 - m0}{m0} \times 100 \quad (2)$$

Where: GR = growth rate (%), m0 = initial measurement (cm), m1 = final measurement (cm).

2.5.3. Vigor

Height and collar diameter of trees are commonly used parameters in tree cultivation. The ratio of these two dendrometric parameters was used to determine the vigor of cashew trees according to the following formula:

$$V = \frac{H}{D} \quad (3)$$

Where: V = vigor, H = plant height (cm), D = collar diameter (cm).

2.5.4. Number of leaves

The number of leaves was used to assess the vegetative development of cashew trees. This parameter involved counting the leaves of cashew trees based on the cropping system during the first year of the study.

2.5.5. Canopy spread

Canopy spread is the (average) measurement of the lateral distance between the two outermost leaves of the cashew tree canopy in the east-west and north-south directions. It was measured to evaluate the lateral growth of cashew trees according to the cropping system. Canopy spread was calculated using the following formula:

$$CS = \frac{\text{N−S measurement} + \text{E−W measurement}}{2} \quad (4)$$

Where:

CS = canopy spread (m), N-S measurement = measurement of canopy spread in the north-south direction (m), E-W measurement = measurement of canopy spread in the east-west direction (m).

2.6. Statistical Analysis

The cropping systems, cashew tree spacing, and their interaction were each subjected to a multivariate analysis of variance (MANOVA) to assess their overall influence on the measured parameters. This helped identify factors that showed a significant effect. The student's t-test was then used for mean comparison. When the probability (P) was ≥ 0.05, it was concluded that there was no significant difference, whereas when $P < 0.05$, at least one significant difference existed among the means. Finally, the chi-square (χ^2) test for independence was performed to evaluate the relationship between variables. The analyses were conducted using the XLSTAT software.

3. Results

3.1. Combined Effect of Plant Spacing and Cropping System on Mortality Rate

Figure 2 presents the mortality rates of cashew trees according to the studied treatments. The highest mortality rates were observed in cashew trees grown in association with groundnuts. Specifically, cashew trees grown in the intercropping system, with spacing configurations of 10 m × 10 m and 12 m × 12 m, recorded respective mortality rates of 31.25% and 25.64%. These rates were lower in cashew trees grown in monoculture at the same spacing, which recorded respective mortality rates of 20.31% and 17.95% for the 10 m × 10 m and 12 m × 12 m spacing. As for cashew trees spaced at 14 m, the mortality rate was the same for both cropping systems at 20.51%.

Furthermore, the chi-square (χ^2) test of independence conducted to determine the relationship between cashew tree mortality and the cropping system, on the one hand, and the plant spacing on the other hand (Table 1), showed that cashew tree mortality is not related to either the cropping system or the spacing between trees ($P > 0.05$).

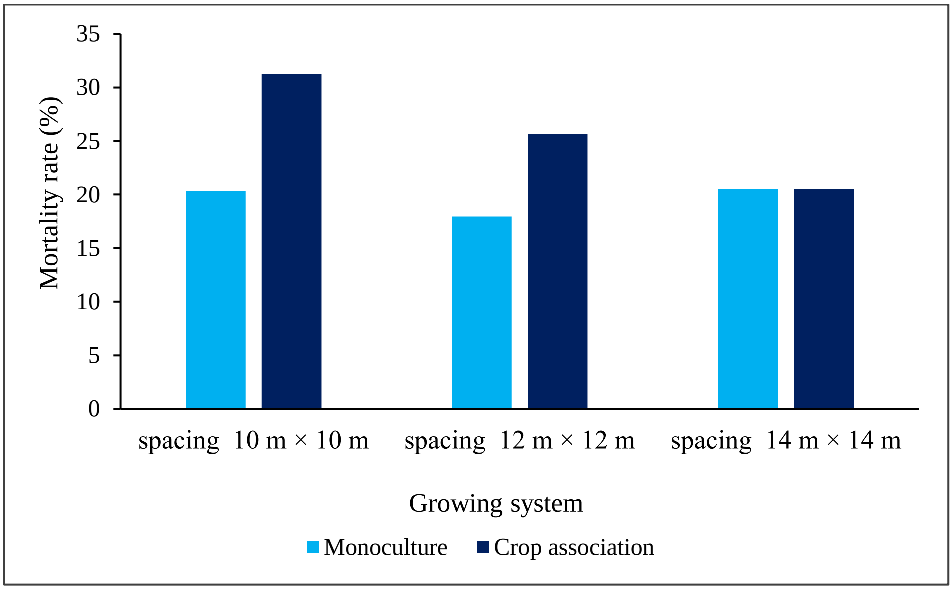

Figure 2. Variation in cashew mortality rate according to cropping system and plant spacing.

Table 1. Results of the chi-squared (χ^2) independence test regarding cashew tree mortality.

Variables	Cashew trees spaced 10 m × 10 m		Cashew trees spaced 12 m × 12 m		Cashew trees spaced 14 m × 14 m	
	X_{obs}	X_{theo}	X_{obs}	X_{theo}	X_{obs}	X_{theo}
Monoculture	13	14	7	7.21	8	6.79
Crop association	20	19	10	9.79	8	9.21
Dl	2					
P	0.77					

X_{obs}: observed value; X_{theo}: theoretical value; Dl: degree of freedom; P: probability.

3.2. Overall Effect of Cropping Systems and Spacing on Cashew Tree Growth Parameters

Table 2 presents the results of the multivariate analysis of variance (MANOVA) examining the overall effect of cropping systems and spacing on cashew tree growth parameters. This test revealed that only the cropping system had a significant effect ($P < 0.05$) on the studied parameters. Consequently, the comparison of means for agro-morphological parameters was conducted based solely on the cropping system through the student's t-test.

Table 2. The overall effect of cropping systems and spacing on growth parameters of cashew trees.

Factors	Dl	P
Spacing	8	0.071
Growing system	4	< 0.0001
Spacing × growing system	8	0.182

Dl: degree of freedom, P: probability.

3.3. Effect of Cropping System on Cashew Tree Growth Parameters

The results of the impact of the cropping system on the growth parameters of cashew trees are presented in Table 3. The Student's t-test indicated a highly significant effect ($P < 0.001$) of the cropping system on all the agronomic parameters studied in the first year of cultivation. Indeed, the growth of cashew trees cultivated in monoculture was faster than that of plants cultivated in association with groundnuts. In comparison to cashew trees cultivated in crop association, the highest values for vigor (37.54), number of leaves (36.01), diameter growth rate (82.30%), and height (116.83%) were observed in cashew trees cultivated in monoculture. The average value for vigor, number of leaves, diameter growth rate, and height of cashew trees cultivated in crop association were 33.83, 18.64, 49.96%, and 60.01%, respectively.

From the second year onward, the growth rates (diameter and height) of cashew trees cultivated in association and in monoculture did not differ significantly ($P > 0.05$). The diameter growth rate of cashew trees cultivated in monoculture and crop association was 43.53% and 40.86%, respectively. As for the height growth rate of the plants, it was 47.12% for cashew trees cultivated in monoculture and 49.71% for those cultivated in association with groundnuts. The Student's t-test also revealed that the vigor of cashew trees cultivated in crop association was higher than those cultivated in monoculture ($P < 0.001$). The average vigor values were 28.84 and 31.98, respectively, for cashew trees cultivated in monoculture and in association with groundnuts. Finally, a significant difference (P < 0.001) was observed in the canopy size of the trees. Cashew trees cultivated in monoculture had a significantly larger canopy (148.39 cm) compared to their counterparts cultivated in association with groundnuts (115.51 cm).

Table 3. Average values of cashew tree growth parameters according to cropping system.

	Variables	Monoculture	Crop association	*Statistics*	
				|t|	P
Year 1	Diameter growth rate (%)	82.30 ± 3.87[a]	49.96 ± 2.75[b]	6.80	< 0.001
	Height growth rate (%)	116.83 ± 6.51[a]	60.01 ± 4.42[b]	7.20	< 0.001
	Vigor	37.54 ± 0.78[a]	33.83 ± 0.68[b]	3.56	< 0.001
	Number of leaves	36.01 ± 2.15[a]	18.64 ± 1.27[b]	6.95	< 0.001
	Canopy spread (cm)	-	-	-	-
Year 2	Diameter growth rate (%)	43.53 ± 1.65[a]	40.86 ± 1.82[a]	1.08	0.277
	Height growth rate (%)	47.12 ± 4.32[a]	49.71 ± 3.33[a]	0.47	0.635
	Vigor	28.84 ± 0.60[b]	31.98 ± 0.65[a]	3.51	< 0.001
	Number of leaves	-	-	-	-
	Canopy spread (cm)	148.39 ± 4.59[a]	115.51 ± 4.10[b]	5.33	< 0.001

Values bearing the same letters horizontally are statistically equal; |t|: value of the t-test; P: probability of occurrence.

3.4. Growth of Cashew Trees According to the Cultivation System

The growth curve shows two distinct phases in the first year of cultivation. The first phase is observed during the first 30 days, where cashew trees exhibit similar growth for both cropping systems. Beyond this period, cashew trees grown in monoculture show more accelerated growth compared to those grown in the intercropping system with groundnuts (Figure 3). This trend differs in the second year of the experiment, where almost identical growth of cashew trees is observed regardless of the practiced cropping system (Figure 4).

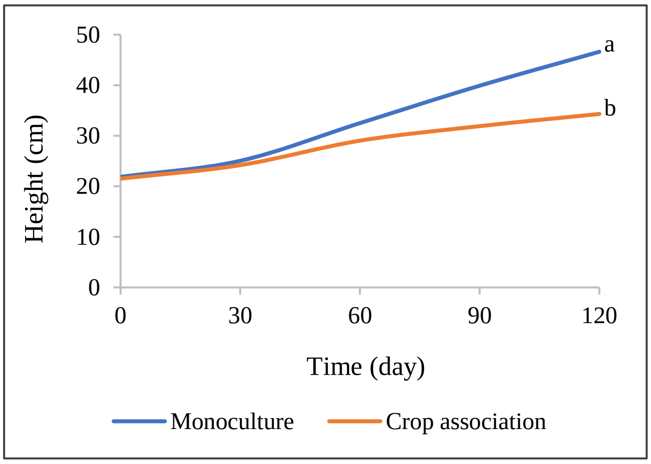

Figure 3. Evolution of cashew tree growth under the cultivation system in the first year of growth. Different letters mean significant differences between the treatments according to student's t-test (P < 0.05).

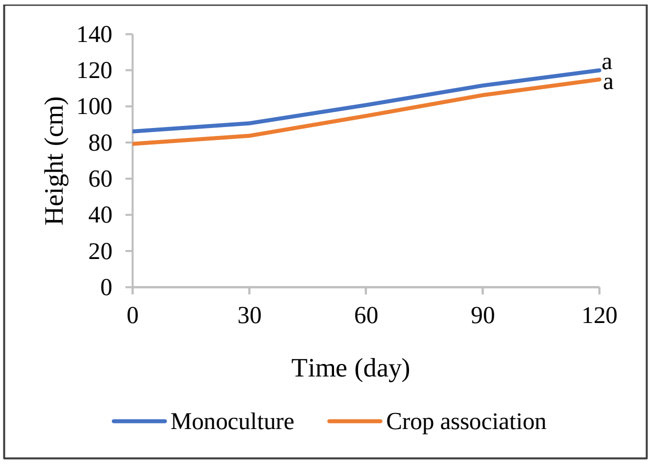

Figure 4. Evolution of cashew tree growth under the cultivation system in the second year of growth. Identical letters mean statistical equality between treatments according to the student t-test (P > 0.05).

4. Discussion

The lack of a significant difference observed in this study between the cropping systems regarding cashew tree mortality may be attributed to certain physical factors. Indeed, the taproots of the cashew trees may have broken during their transport to the field or during handling before planting, which could have led to their mortality. Working on the vegetative growth and grafting ability of two cashew genotype, Djaha et al. (2012) also indicated that root breakage in young cashew trees is the primary cause of their mortality after transplantation. Cashew tree mortality could also be attributed to the low quantity of organic matter and poor fertility of the experimental site. Indeed, the soils in the experimental area

(Tchologo region, northern Côte d'Ivoire) are generally deficient in organic matter (Akanza & N'Guessan, 2017). Consequently, young and delicate cashew trees, which had not received any amendments, were unable to withstand the edaphic conditions of the environment. This observation is in line with the findings of Tokore Orou Méré et al. (2022), who revealed that newly planted cashew trees fertilized with organo-mineral fertilizers had a lower mortality rate than those cultivated without fertilizer inputs.

The slow growth of cashew trees cultivated in association with groundnuts in the first year indicates potential interspecific competition. This result is largely attributed to the timing of groundnut planting. Indeed, planting the legume one week after establishing the cashew tree may have been a short interval. The young plants may not have had sufficient time to adapt and establish their roots properly to utilize the available resources. The intercropping may have consequently caused water and/or nutrient stress in the young cashew trees, observed starting from the 30th day of association. This date corresponds to the flowering period of groundnuts, during which they require significant amounts of water and mineral nutrients for pods and seed formation (Raphiou et al., 2020; Civil, 2022). Djè Bi et al. (2017) also highlighted that the planting timing is a factor that influences the growth of associated crops. These authors further reported that cassava's growth and development are limited when cultivated concurrently with groundnuts. However, the best agronomic performances of cassava (number of leaves, stem diameter, stem length) were observed when the cucurbit was planted at least 15 days after cassava planting. Similarly, the work of Legodi and Ogola (2020) showed that legumes (cowpea, chickpea, and pigeon pea) planted later between cassava plants do not exert significant competition on them.

One of the reasons for the improved growth of the trees observed in the second year of this study could be attributed to the fact that cashew trees had a greater competitive advantage for mineral elements compared to groundnuts. Indeed, at 12 months of age, cashew trees could explore a large volume of soil through the development of numerous lateral roots. These roots likely exerted sufficient competition for water and mineral elements present in the soil. This observation aligns with the findings of Mansaray et al. (2022), who indicated that well-established cassava plants (at 5 weeks of age) develop enough roots to compete with secondary crops like groundnuts, cowpeas, and soya beans. Consequently, a harmonious growth of cassava plants (height, stem diameter, and crown diameter) was observed under these cultivation conditions.

On the other hand, cashew trees cultivated in association may have benefited from the residual effects of the legume in the second year of cultivation, thus promoting the growth of their stems. Furthermore, plants with large stem diameters typically have a well-developed root system (Day et al., 2010). This correlation may have allowed the intermingling of cashew tree roots with those of groundnuts. This mechanism enables the transfer of nitrogen fixed by the legume during the crop association (Akanza & N'Guessan, 2017). This potential nitrogen nutrition would have accelerated the growth of cashew trees cultivated in association, helping them catch up in height with those cultivated in monoculture. Additionally, groundnuts may behave like some legumes that initially compete during the early years of association but eventually benefit the main crop. This is the case with alfalfa, which can hinder tree growth in the early years of cultivation. The benefits of this legume are observed after a few years, promoting tree growth (Coulon et al., 2000). The growth results of cashew trees obtained in the second year of this study corroborate those of Opoku-Ameyaw et al. (2011), who showed no significant difference between cashew tree association with groundnuts and cashew tree monoculture in terms of stem base circumference and tree height. The results of Santimaitree (2010) also revealed that the height and stem circumference growth of young rubber trees cultivated in monoculture and in association with groundnuts were similar.

5. Conclusion

At the end of this study, we conclude that the mortality of cashew trees is not linked to any of the factors studied (crop system and planting density). Additionally, there is competition between groundnuts and young cashew trees in the first year of their combined cultivation. This leads to a slowdown in the development and growth of cashew trees in association, unlike those grown in monoculture, which exhibited the highest values in terms of vigor, leaf count, and growth rates (height and stem diameter). However, the growth delay of young cashew trees grown in combined cultivation is compensated for from the second year of cultivation, characterized by a height and stem diameter similar to those grown in monoculture. Hence, based on the findings of this study, it would be advisable to sufficiently separate the groundnut planting points from the cashew tree plants to avoid potential competition in the first year of cultivation.

Conflict of Interest

The authors declare that they have no conflict of interest.

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