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Explanatory factors of *Zea mays* var *FBC6* yields in the *Anacardium occidentale* L. Parklands at Logofourousso in Western Burkina Faso

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAT set up the field experimentations, carried out the laboratory tests and contribute to the writing of the article. Author JY developed the study protocol, supervised the fieldwork and contributed to the writing of the article; Author PO granted the quality and effectiveness of the field works and the writing of the article. All authors read and approved the final manuscript.

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ABSTRACT

Initially introduced to orchards in Western Burkina Faso, *Anacardium occidentale* L. is a woody component in Agroforestry parklands. Its influence on crop performance is a concern for growers. The main objective of the present study is to characterize the interactions between *Anacardium*

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occidentale and *Zea mays*. Specifically, it aims to determine the factors influencing maize development in cashew parklands, and to assess maize yields in these parklands. So, experiments were carried out during two rainy seasons from 2021 to 2022, on plots of Cashew-Maize and Maize alone, with three replications each of them. Some parameters supposed to explain the maize yields were measured on the two systems : Soil physico-chemical compositions have been determined from 0-40 cm under the ground ; parameters were measured in terms of soil humidity from 0 to 60 cm, and plant height growth during the vegetative phases of the crops. The maize photosynthetic assimilation was also measured on maize plants. The root excavations have been done to establish cashew and maize root systems from 0 to 60 cm depth. At last maize yields concerning were evaluated on the two production systems. Data were statistically analyzed using XLSTAT software. The cashew-corn plots showed a C (0.21%), N (0.02%), P (0.91 mg/kg) and K (29.59 mg/kg) content for the 0-20 cm horizon. These values are similar for the maize-only system, and are less than 1%. Soil humidity also increased with depth in both systems. The numbers of maize roots predominate in the 10-15 cm horizons, while cashew roots are concentrated 35-40 cm below the soil surface. Chlorophyll uptake during the crop maturity phase between the systems was not significant ($P<0.72$), with an average value of 0.009 (±0.004) mg/mm2/day for the cashew-corn system. Grain production was estimated at 0.31±0.16 kg/m2 for the cashew-corn plots. Beyond the socio-economic interests that justified its introduction into the Agrarian landscape, *Anacardium occidentale* is a species that does not interfere negatively with annual crops.

Keywords: Agroforestry parklands; Anacardium occidentale; Zea mays var FBC6; interaction; yield.

1. INTRODUCTION

In Sahelian Africa, the traditional production system remains the agroforestry parkland system [1,2]. Agroforestry parklands are fields on which annual crops are grown in combination with trees preserved from natural or introduced vegetation by farmers after clearing woodland areas to make crop fields. These agroforestry parklands represent mixed farming systems where interactions between the main components (trees, crops and animals) have always been a determining factor in the management choices applied by farmers [3]. Indeed, the choice of species, their density and their arrangement in cultivated plots depend on the socio-economic and ecological benefits they bring to the population. Most farmers in the semi-arid zones of West Africa consider trees to be an integral part of the production system [4,5]. Worldwide, studies on these combinations have attracted the attention of many scientists. Indeed, one of the first such studies dates back to the 1960s [6] and determined the influence of *Acacia albida* on crop field soils. In Burkina Faso, agroforestry parklands are mostly characterized by unfavorable soil and climate conditions. The soils are shallow (generally limited by a cuirass, which in some places outcrops on the surface), naturally poor in organic matter and deficient in phosphorus and nitrogen. Over 85% of the country's soils are leached tropical ferruginous types [7]. Nowadays, numerous studies aim to promote sui Revised-ms_IJPSS_103832_v1 cultivation techniques for better yields from the agroforestry parklands that dominate the country's major zones. According to [8], *Anacardium occidentale* is the third most important species in Western Burkina Faso, after *Vitellaria paradoxa* and *Parkia biglobosa,* which represent the characteristic species of the zone's agrosystems. The same authors also noted significant associations of the species with maize. However, farmers remain sceptical about *Anacardium occidentale* contribution to the improvement of annual crops. It’s this context that the present study has been initiated, with the general aim of characterizing the interactions between *Anacardium occidentale* and *Zea mays*. Specifically, the aim was to determine the factors influencing maize development in cashew parklands, and to assess maize yields in these parklands.

2. MATERIALS AND METHODS

2.1 Study Site

The study site is the province of Houet in Western Burkina Faso, precisely in the village of Logofourousso located 10 km from Bobo-Dioulasso (fig. 1). The village's population is made up mainly of Bobo natives, with a few Mossi, Peulh and other migrants. The main activities are agriculture, livestock breeding, exploitation of forest and wildlife resources, eco-tourism, handicrafts and petty trade. Bobo-Dioulasso, where the village is located, is the country's second most populous commune, with 983,552 inhabitants [9]. It is located in the South Sudan climate zone, with average annual rainfall between 1,100 - 1,200 mm. This rainfall is distributed over 60 to 90 rainy days. The Southern Sudanian sector is home to savannahs that vary qualitatively in size, density and floristic composition. There are shrub savannahs, tree savannahs, wooded savannahs, open forests, gallery forests and riparian formations [10]. The soils in this area are ferrallitic, modally reworked soils with low desaturation. They are characterized by a sandy-loam texture on the surface (first 30 cm), and silty-clayey-sandy deeper down, with low organic carbon and total nitrogen content [11,12].

2.2 Experimental Setup

In order to have a better understanding of cashew-corn interactions, the experimental setup consisted of two types of plots, each with 3 replicates of them : plots with maize alone (M) and plots with cashew and maize crops (Ana-M). The size of each plot was 2500m^2. The average tree density in the selected plots were 63 plants /ha. The criteria used to select the plots were the variety of maize grown, tree density and homogeneity of treatment (organic inputs and different sizes) over the last five years. The selected plots were ploughed beforehand. Sowing were sown at a spacing of 0.80 m between rows and 0.40 m between bunches, with two plants per bunch. Sowing took place in mid-July.

2.3 Measured Parameters

2.3.1 Soil physico-chemical properties

Samples were taken on all six plots. They were taken from the top forty centimetres of soil (maize root concentration horizons) from the top of the ridge or on the flat ground. On each plot, three (3) samples were taken along the diagonals using a graduated auger. A composite sample weighing 900 g was taken from these 3 samples from the 0-20 cm and 20-40 cm horizons. All the samples taken were air-dried and sieved by hand. This made it possible to separate coarse elements (CE ; fraction > 2 mm) and Fine Elements (fraction < 2 mm). The pH-water, pHKCl, organic carbon (C) expressed on % of soil and assimilable phosphorus (Pass) expressed in mg/kg of soil were determined on the fine soil. Water (pH) was measured with a pH meter using the electrometric method. The soil per water ratio was 1 per 2.5. pHKCl was

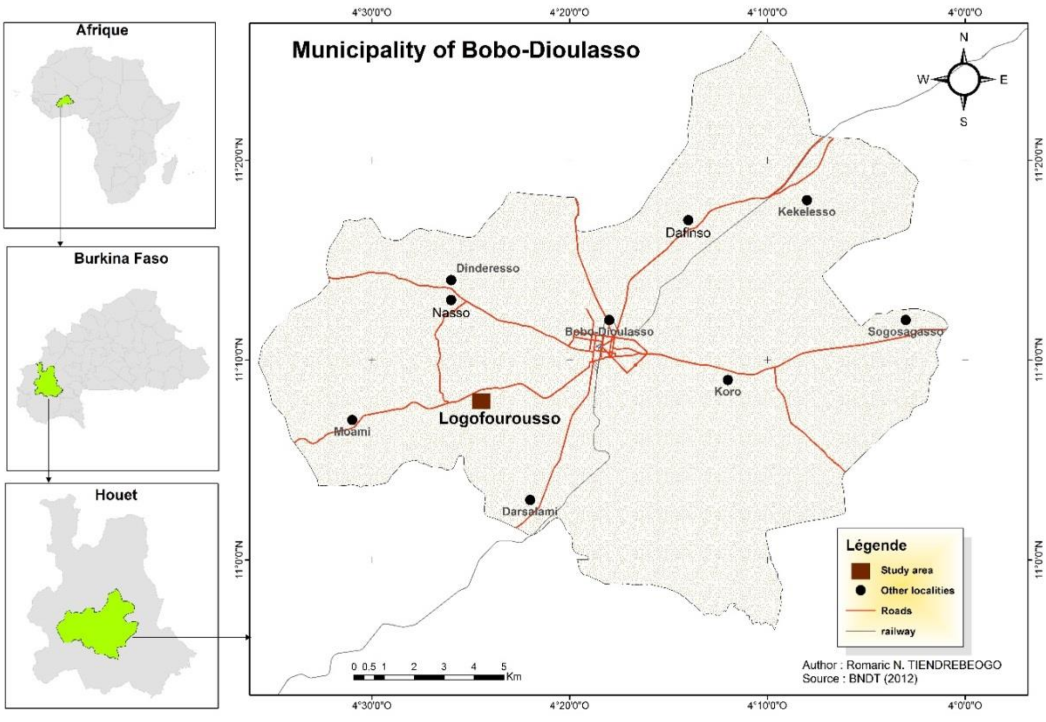

Fig. 1. Location of study sites

determined by the same method using a potassium chloride solution. Carbon was determined by the Walkley-Black method. Assimilable phosphorus was determined by the Bray-1 method. Analyses were carried out at the laboratory of the Environment and Agricultural Researches Institute (INERA) at Farako-Bâ/Bobo-Dioulasso, using procedures in line with those of [13].

2.3.2 Soil humidity content

Soil humidity content measurement were taken 24 hours after a rainfall of around 20 mm during the sowing, bolting and ripening periods on all plots, at soil depths ranging from 10 cm to 60 cm [14]. Using a graduated auger, three soil samples were taken every 10 cm (photo 1-a) at three points at least 1 metre apart on each plot [14]. Mixing the samples from the three sampling points produced a composite sample corresponding to each sampling depth, which was then dried. For drying, the samples were placed in an oven (THERMOSI SR 2000, France) set at a temperature of 105°C ± 3°C (photo 1-b) for 24 hours [14,15]. A 10-2 precision balance (Sartorius, USA) was used to weigh the samples at the time of sampling and after the drying time in the oven. The weight humidity content (Hp) is given by the following formula :

$$\mathbf{Hp}(\%) = \frac{\mathbf{Mh}\,(\mathbf{g}) - \mathbf{Ms}\,(\mathbf{g})}{\mathbf{Ms}\,(\mathbf{g})} * 100$$

Mh = Mass of wet sample Ms = Mass of dried sample

2.3.3 Photosynthetic assimilation of maize

The photosynthetic assimilation was measured on maize plants located under and outside the crowns of each crop plot. Four under-top and four outside-top corn plants were selected for each plot. The vegetative development of the selected plants was almost identical. On each selected maize plant, the third or second healthy adult leaf not senescing from the top was identified. Ten leaf discs were taken from a part of the leaf divided into two parts by the main vein (photo 2-a) in the morning, before sunlight appeared, and another ten were taken from the remaining part of the same leaf (photo 2-b) in the evening, after sunset. Each sample of ten discs was wrapped in aluminum foil and protected from sunlight. All samples were oven-dried at the INERA/Farako-Bâ laboratory for 24 hours at a temperature of 105 ± 3°C. On leaving the drying oven, they were weighed on a 10^{-1}mg precision electronic balance. The dry matter of the samples was thus obtained by the difference in weight between the evening and morning samples.

The daily chlorophyll assimilation rate (TAC) was calculated using the following formula :

TAC((mg/mm)/day) = Dry weight mg (evening)-Dry weightmg (morning) / Leaf area(mm-2)

2.3.4 Root profiles of *Anacardium occidentale* and *Zea mays*

According to [16], the study of root systems is necessary for the evaluation of tree-crop interactions. To assess the co-existence of cashew and maize roots, root profiles were established. For this study, a rectangular pit 1 m long, 60 cm wide and 60 cm deep was dug at the foot of the cashew-maize plots using shovels and pickaxes. The length of this pit was used as a profile face on which to carry out root counts (photo 3). The operation consisted in carefully freeing the roots on the profile side with a knife, then counting them in 5 cm x 5 cm squares on a 1 m x 60 cm grid fixed to the profile side [14].

2.3.5 Maize cob, grain and stover yields

In two successive cropping seasons (2021 and 2022), crop yields were assessed on tree-crop and pure crop plots using the yield square method [15]. On each plot, three yield squares (dimensions 5 m x 5 m) were randomly delimited and bounded by stakes from the sowing period. These stakes remained in the ground until the end of the harvest. The average yields of the squares were reported at plot level in tons/ha. The parameters assessed were harvested cob weight, dry kernel weight and corncob weight.

2.3.6 Statistical analysis of data

Analysis of variance (ANOVA) at the 5% threshold was used to compare the means of the calculated parameters. The R studio software version 4.1.1 and the R Commander package version 2.7-1 were used to perform the various comparison tests. Correlation tests between the various factors likely to influence corn yield were carried out using Minitab 19 software. The value of the correlation coefficient measures both strength and direction of an association. If it varies from 0% to 100%, the correlation is strong when its value is close to 100%, it is average when the value is close to 50% and weak when the value is close to 0%. Linear regressions linking performance on the ordinate and the various explanatory factors on the abscissa were carried out for this purpose.

2a. Sampling with an auger

2b. Oven drying of samples

Fig. 2. Soil humidity determination process

3a. Sampling of morning washers

3b. Sampling of evening washers

Fig. 3. Sampling of washers for chlorophyll assimilation studies

Fig. 4. Establishing root profiles

3. RESULTS

3.1 Physico-Chemical Characteristics of the Parkland Soils

3.1.1 Soil physical characteristics

The results in Table 1 show the soils in the Ana-M system have a sandy-silty surface texture. For the M system, the texture is sandy-silty on the surface to sandy-clay at depth. These results show a high degree of similarity between the two systems studied. The physical elements presented in this table show that in the horizons considered, total sands exceeded 60%, inducing poor retention of fertilizing elements and water for crops. The clay content is below 25% for the first 20 cm of soil, which is characteristic of soils that are not very heavy and less difficult to work.

2.1.1.1 Soil chemical characteristics :

The results of the soil chemistry analysis are presented in Tables 2 (a, b and c). The pH-water of both systems ranged from 5.23 to 5.58 for the depths considered. The soils on the experimental plots are acidic according to [17] standards. Organic matter, nitrogen and carbon content is below 1% for both systems. These values characterize poor soils according to the BUNASOL land evaluation manual (1990). However, the average total phosphorus (P) content in the Ana-M system is 46.67 mg/kg soil, of which 0.77 mg/kg is assimilable. The average total potassium content is 553.88 mg/kg, but only 26.96 mg/kg of this is available to plants. Nitrogen content varies from profile to profile to within 0.01. Total carbon content is highest in the upper layer of the M system alone (0.33%). The average values in the first 0-20 cm of soil are 0.21% and 0.33% for the Ana-M and M systems respectively.

3.1.2 Soil humidity evolution

The Fig. 5 shows the evolution of soil humidity in the systems at different depths. Differences in soil humidity content were observed as a function of production system, measurement period and soil depth ($P < 0.002$). The Ana-M system had a higher humidity content than the M system alone. Whatever the system, soil humidity was higher first at sowing time, then at heading and finally at crop maturity. Soil humidity also increased with depth in both systems.

Table 1. Soil particle size composition of the systems

Systems	Horizon (cm)	Argile %	Total silts %	Total sand %	Classe texturale
Ana+M	0 – 20	7,76	6,11	86,14	SL
M seul		16,72	12,44	70,84	LS
Ana+M	20 – 40	11,99	5,09	82,92	SL
M seul		23,53	15,69	60,78	LAS

SL : Sand silt, LS : Silt sand, LAS : Silt clay sand

Table 2. Soil chemical characteristic according to formation type and depth at Logofourousso

Table 2a. Chemical characteristic of horizons 0-20cm

Element	Ana+ Maïs	M seul	*F value*	*P value*
PH water	5,23±0,20	5,58 ±0,16	3,11	0,08
PH KCL	4,07±0,30	4,18±0,32	2,52	0,13
C Organic (%)	0,21±0,02	0,33±0,12	0,94	0,46
M Organic (%)	0,36±0,04	0,57±0,21	0,94	0,46
Total N (%)	0,02±0,00	0,03±0,01	1,12	0,39
C/N	10,54±0,60	9,71±1,09	1,23	0,35
P total(mg/Kg)	37,29±20,75	204,35±123	1,11	0,40
P Bray1(mg/Kg)	0,91±0,32	12,44,16,72	0,73	0,56
K total(mg/Kg)	351,93±117,32	753,20±118,68	1,98	0,19
K dispo(mg/Kg)	29,59±7,11	36,17±18,33	0,52	0,67
Ca ech (cmolc kg-1)	1,07±0,38	2,07±1,59	0,60	0,63
Mg ech (cmolc kg-1)	0,28±0,13	0,67±0,16	1,15	0,38

Table 2b. Chemical characteristic of horizons 20-40cm

Element	Ana+ Maïs	Maïs	*F value*	*P value*
PH water	5,35±0,23	5,56 ±0,27	1,04	0,42
PH KCL	3,96±0,36	4,19±0,16	1,17	0,37
C Organic (%)	0,17±0,05	0,31±0,05	0,79	0,52
M Organic (%)	0,31±0,08	0,54±0,1	0,79	0,52
Total N (%)	0,02±0,00	0,03±0,01	1,27	0,34
C/N	9,66±1,93	9,96±1,23	0,08	0,96
P total(mg/Kg)	41,87±13,41	192,48±134,05	0,87	0,49
P Bray1(mg/Kg)	0,77±0,35	12,62±18,61	0,67	0,59
K total(mg/Kg)	498,21±116,96	948,6±177,24	1,69	0,24
K dispo(mg/Kg)	24,33±6,03	38,80±22,78	0,77	0,54
Ca ech (cmolc kg-1)	0,80±0,26	1,70±0,60	0,51	0,68
Mg ech (cmolc kg-1)	0,27±0,09	0,77±0,13	1,59	0,26

M.O (%): organic matter rate; C: carbon; N-tot: nitrogen rate; P-tot: total phosphorus; P_Bray1: assimilable phosphorus; k-tot: total potassium; K_dispo: available potassium; M alone: Maize alone; Ana alone: Cashew alone; H: Horizon , Ca exch: exchangeable calcium; Mg exch: exchangeable magnesium.

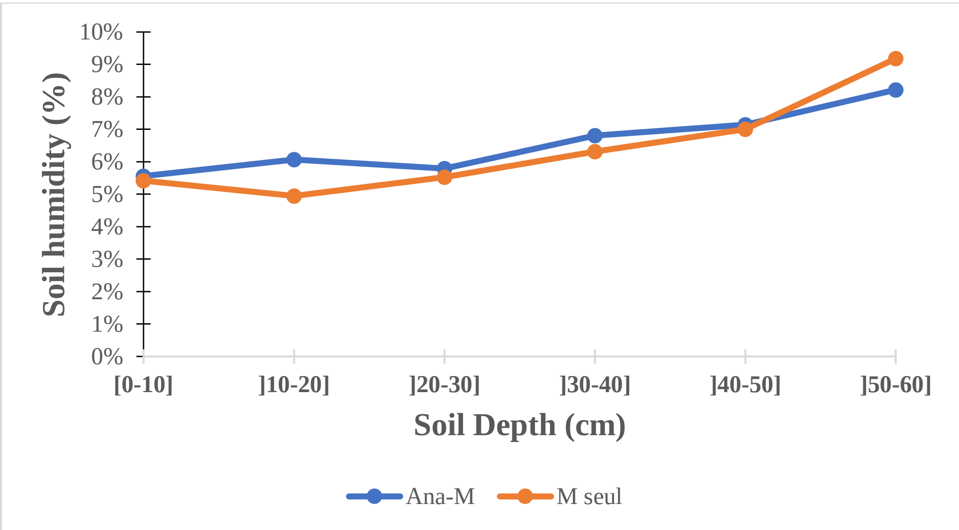

Fig. 5a. Soil humidity content at planting time

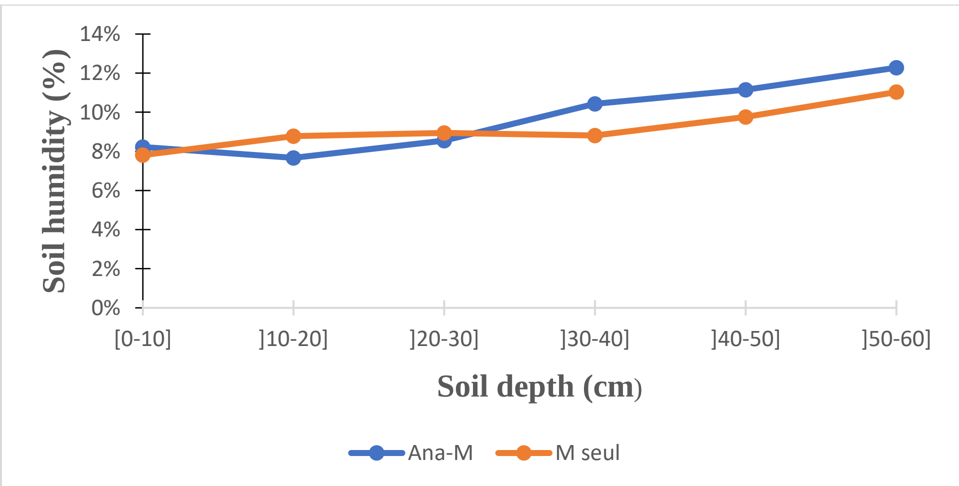

Fig. 5b. Soil humidity levels during crop lifting

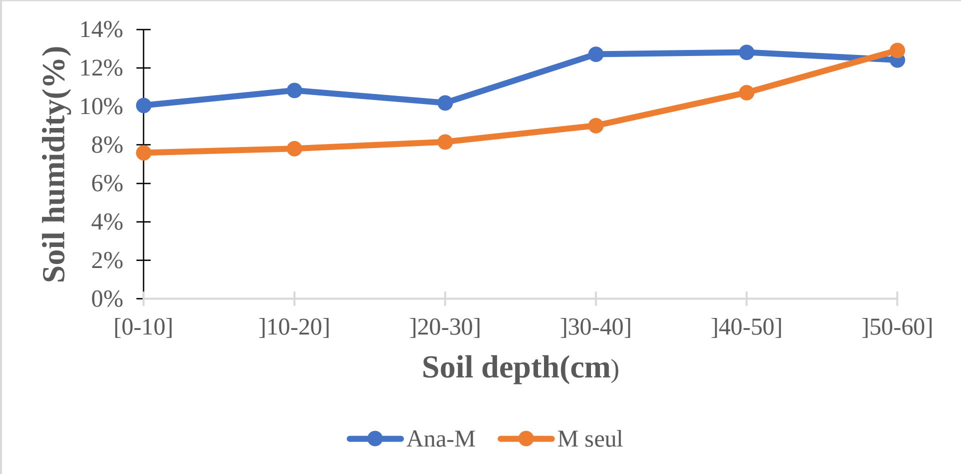

Fig. 5c. Soil humidity content at crop maturity

Fig. 5. Soil humidity of the systems as a function of depth during the different phases

3.1.3 Coexistence of maize and cashew roots

Fig. 6 shows the mean numbers of *Anacardium occidentale* and *Zea mays* roots as a function of soil depth in the Ana-M plots. The differences are highly significant (p = 0.000). For maize, the highest number of roots (66) was observed at the 10-15 cm soil horizon. For cashew, the greatest number of roots (130) was observed in the 35-40 cm soil horizon (Fig. 3). From this study, we can see that *Zea mays* var *FBC6* roots are concentrated in the superficial layers of the soil, while those of *Anacardium occidentale* occupy the deeper layers.

3.1.4 Chlorophyll assimilation

Chlorophyll uptake is highest during the bolting phase. Statistical analysis between systems during this phase reveals a non-significant difference (P = 0.72). However, the highest average chlorophyll uptake was observed in the M system alone, with a value of 0.01 ± 0.002 mg/mm2/day. At the heading stage, chlorophyll assimilation values drop in all three production systems. The highest mean value was 0.004 ± 0.001 mg/mm2/day in the M system alone (Fig. 7). The same trends were observed at crop maturity.

3.1.5 Cob, grain and stover yields by production system

Yield data for 2021 are similar to those for the 2022 season. Table 3 shows the average cob, grain and stalk yields for each of the Ana-*Zea mays* (Ana-M) and *Zea mays* alone (M) systems in tonnes per hectare. Statistical analysis revealed highly significant differences between the yields of the three systems in terms of harvested ear weight (P = 0.001). The highest cob yields were recorded in the M-only systems (4.66 ± 0.16 t/ha) and the lowest in the Ana-M systems (3.66± 0.28 t/ha). Grain weights in the three systems were statistically different (P= 0.03). Grain production was highest in the M system alone (3.92 ± 0.02 t/ha). Grain production in the three systems were statistically different (P=0.01). Grain production was highest in the system without M trees (3.92 ± 0.02 t/ha). The order of stalk weights was as follows : M>Ana-M.

Fig. 8a shows a positive correlation between ear yield and soil humidity at sowing. However, this correlation remains weak (R^2=19.5%). This result shows that soil humidity at sowing would influence yields. The R^2 values for the bolting and maturity phases are 21.6% and 9% respectively. This shows that 21.6% of yield variation can be explained by humidity in the bolting phase and 9% in the maturity phase.

Figs. 9a-9c show a negative correlation between cob yield and chlorophyll assimilation during the different stages of maize development. The R^2 values (36.4 and 18.1) for the bolting and heading phases respectively remain low. As for the maturity phase, the R^2 value remains average (57.9). These results show that 36.4%, 18.1% and 57.9% of yield variation can be explained by chlorophyll assimilation at bolting, heading and maturity respectivel.

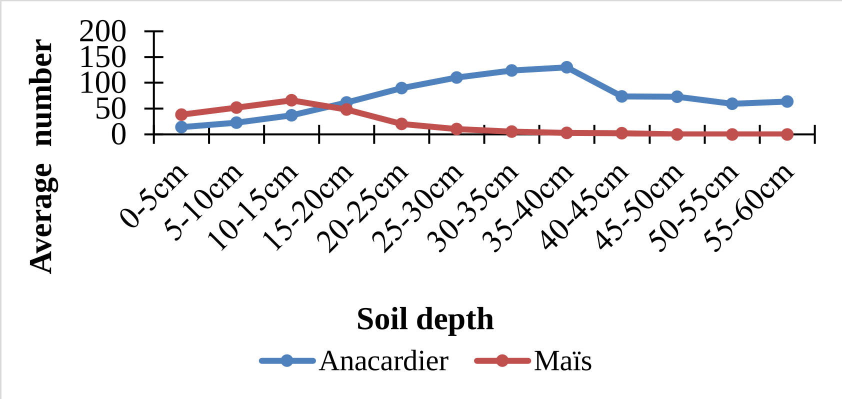

Fig. 6. Average numbers of root of cashew and maize according to soil horizons

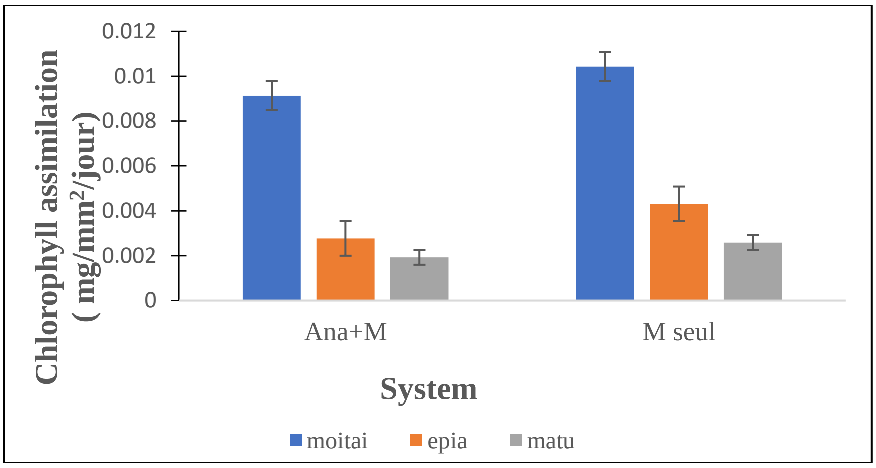

Fig. 7 Chlorophyll assimilation of maize by production system

Table 3. Average yields (t ha-1) in ears, grains and cobs for agroforestry park production systems

Element	Ana-M	M seul	P	Critical value for F
Cob	3,66±0,28	4,66±0,16	0,00	1,31
Grain	3,10±0,03	3,92±0,02	0,01	1,31
Stover	0,55±0,05	0,73±0,08	0,00	1,31

4. DISCUSSION

4.1 Soil Quality In *Anacardium Occidentale* Parklands

Results for soil physico-chemical parameters showed no statistically significant difference between the two systems. However, concentrations of major nutrients (nitrogen, potassium and phosphorus) in maize were low in both systems [17]. It should also be noted that the pH water of the soils on both types of plot ranged from 5.23 to 5.58. This reflects the acidity of these soils. Indeed, according to [18], a water pH indicates highly acid soils if values are between 5.1 and 5.5. The surface soil texture of both systems is sandy-loam. The similarity in surface texture could explain the yield results on the systems. Our results corroborate those of [19], who showed that the difference in yield between varieties of a given species would be due to the chemical properties and texture of the soil. A study of the physico-chemical characteristics of Logofourousso soils shows that sandy texture dominates in the superficial horizons of Ana-M systems. The C/N ratios are also low. These results reveal the constraints and aptitudes of the sampled soils. According to [13], a low C/N ratio reflects very difficult rooting conditions, nutrient availability and nutrient retention capacity. Indeed, several authors indicate that the rooting process of plants on a given soil is essentially influenced by its texture and structure. In the Hauts Bassins region of Burkina Faso, these rooting conditions are a major problem for annual crops on shallow, indurated ferruginous and ferrallitic soils [10,7]. Several authors recommend ploughing and ridging to improve the texture of soil horizons [14]. This will ensure good penetration and root development of the crops. Also, in the present study, good vegetative development of annual crops were observed in the M system alone. This may be linked to the higher C, N and P contents in the first twenty centimetres (20cm) of soil in this system. In addition, the pH of the water is also more favorable to the availability of these elements. Yields were almost identical for both production systems. These results show that other factors, in addition to the presence of trees, can give good yields. Environmental factors that can affect photosynthesis include lack of water, amount of sunlight, soil type and temperature. In this study, favorable water conditions were noted on the Ana-M plots. Also, the trees improve the microclimate in the influence zone of their crowns. This can promote an increase in the number of microorganisms in the environment, leading to an accumulation of soil organic matter in the tree rooting zone compared with open areas [20]. Indeed, studies have reported that *Guiera senegalensis* and *Piliostigma reticulatum* have been identified to promote fungi, microbial diversity and litter decomposition [5]. The presence of micro-organisms in the tree rooting zone is due in part to the fact that phosphorus, an essential ecosystem element, is not present in the soil [21,22].

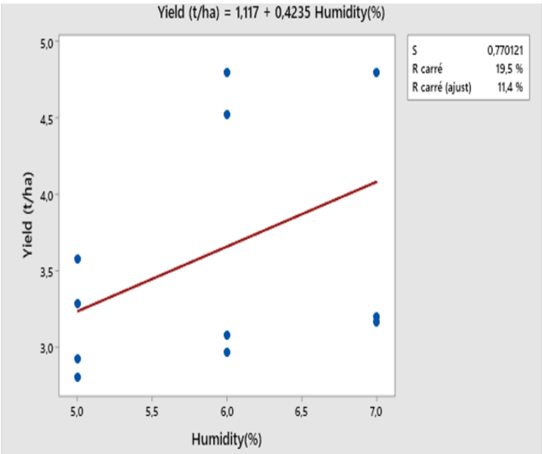

Fig. 8a. Ear-humidity correlation at sowing

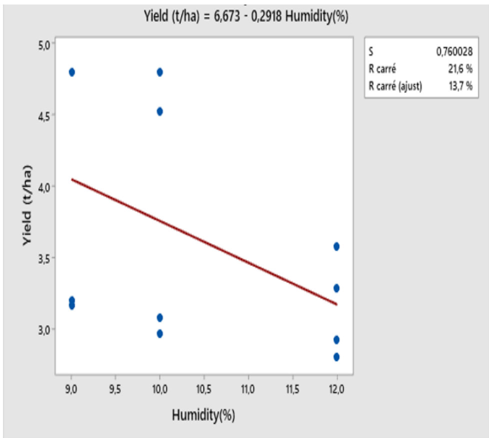

Fig. 8b. Ear-humidity correlation at bolting

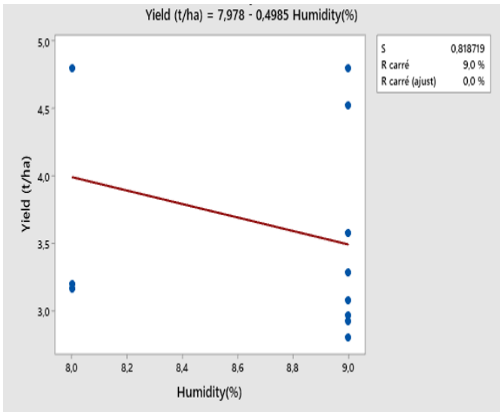

Fig. 8c. Ear-humidity correlation at maturity

Fig. 8. Correlation between corn yield on the cob and soil humidity at different vegetative stages at Logôfourousso.

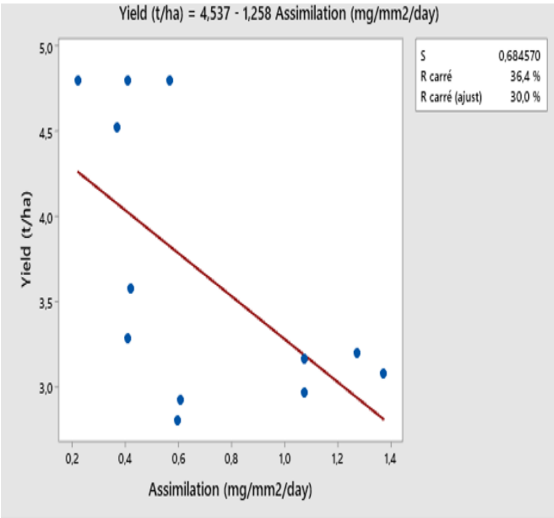

Fig. 9a. Correlation between ears and assimilability at bolting

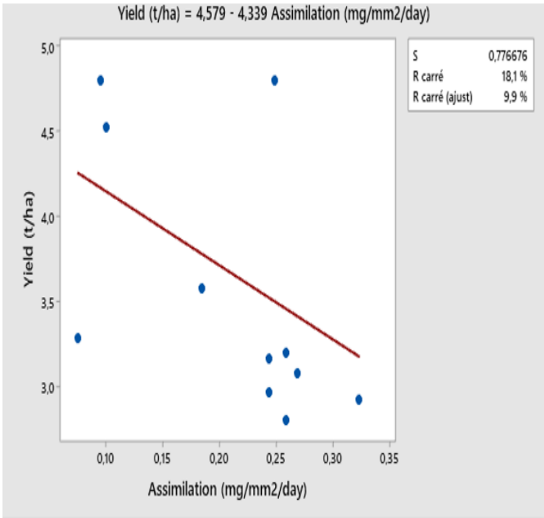

Fig. 9b. Correlation between ears and assimilability at heading

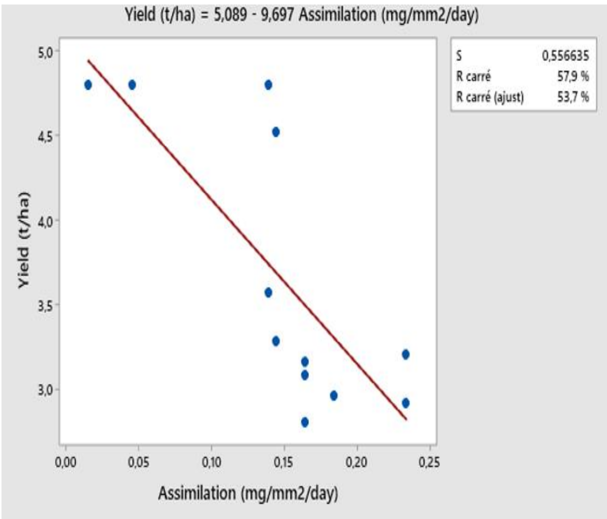

Fig. 9c. Correlation between cobs and assimilation at maturity

Fig. 9.Correlation between maize cob yield and chlorophyll assimilation at different vegetative stages at Logôfourousso

Soil humidity assessed during the three vegetative phases in the two crop years (2020/2021 and 2021/2022) was better on plots with tree combinations. Indeed, variations in the amount of water contained in soil samples were characterized by highly significant differences in the present study. Soil humidity, which is low at the start of the cropping season (sowing), rises during the mid-season (heading) and falls at the end of the season (maturity). These results show the importance of trees in maintaining humidity levels in agricultural plots. Our results corroborate those of [23,14], who worked respectively at Watinoma and Siniéna in the Southern and Cascade Regions of Burkina Faso. For this study, the best humidity levels were obtained in the *Anacardium occidentale -Zea mays* systems, as the trees, which were well pruned at the beginning of the season, intercept little rainwater. These results confirm the ameliorative effect of woody plants and vegetation in maintaining soil humidity. Indeed, improved soil humidity positively influences the development of crops, particularly maize, which is a water-demanding species [23,24]. According to several Authors, the high humidity under the crowns of woody plants can also be attributed to their shading effects [25,24]. This shading effect contributes to climate regulation. The reduction in water potential is responsible for enormous consequences for maize functioning [23,24,14]. Soil water content and plant water requirements are closely linked to the periods of vegetative phases [14]. The low soil humidity levels observed during crop sowing and ripening are essentially due to irregular rainfall at the beginning and the end of the season. In addition, the pockets of drought that very often occur after crop sowing could be the cause of these low humidity levels at these times of the season. During the maize heading-flowering period, the crop's water requirements were met by high rainfall in August and September. Our results confirm the link between humidity conditions and crop production.

4.2 Crop Development Parameters

The results on chlorophyll assimilation have shown that the phenomenon of dry matter production in plants is linked to soil humidity. Indeed, dry matter production is the primary factor in photosynthesis. This production is a better identifier of the plant's hydric functioning during a drought [24]. During pockets of drought, plants regulate water loss by closing stomata or reducing transpiring surfaces. In maize, this stomatal closure is characterized by leaf curling [26]. This action has a major impact on photosynthesis. Photosynthesis is therefore a multifactorial reaction, taking place in conjunction with several elements, and these links are very important. In the systems studied, the low values for chlorophyll assimilation were due to the fact that not all the conditions listed for photosynthesis to take place were present in these systems. In the systems without trees, light was available and soil humidity was lacking ; whereas in the systems with trees, sunlight was lacking in places, especially in the crowns. Excessive soil humidity combined with insufficient light under the cashew tree canopies seems to have resulted in poor development of the maize plants. The height and weight of kernels per plant were relatively higher outside the crowns than under the crowns of both trees. The results obtained during this activity show that the chlorophyll assimilation rate in systems with the tree combination is lower than in systems without trees. This low level of assimilation rate observed in systems with trees could not be attributed solely to a water deficit, as in these systems the soil was very often wet during the rainy season. It may therefore be due to the shading effect of the tree crowns. Similar observations have been made by several authors [27,24,14]. In their studies, they claimed that the reduction in dry matter production under trees was partly due to insufficient light. However, in this study, the values obtained in the treeless plots were not significantly higher than those obtained in the systems with our dominant woody species. It therefore seems clear that *Anacardium occidentale* has a positive impact on photosynthesis in maize crops, but requires silvicultural treatment to ensure good air circulation and improved interception of solar radiation.

Analysis of root profiles in Ana-M systems shows that up to around 15-20 cm soil depth, the concentration of *Anacardium occidentale* roots is low and starts to become significant beyond this depth. The root profile of many cultivated maize varieties has well-developed root systems in the first 30 cm of soil. These results suggest that there is little root competition between cashew and maize in the different soil layers. These types of root profile had been found in roasting plantations in Senegal and at Siniéna in the Cascades in Burkina Faso [28,14]. These Authors showed that the Borassus root system remains weakly developed in the superficial layers of the soil down to a depth of 30 cm. This parameter allows cereals to develop well alongside this species. In the present study, we have seen cashew root systems that remain weakly developed from the first cm of soil down to a depth of 15-20 cm.

Yields are significantly reduced at tree crown level. This reduction is less pronounced as one leaves the shaded area [27,22]. The drop in yield under cashew is largely attributed to the shading effect, which results in insufficient light intensity, much of which is captured by the tree crowns. Conversely, better yields on maize-only plots can be explained by higher maize densities on treeless plots. Despite this competition for light, cashew trees help to maintain and improve soil quality. In terms of productivity, our results showed that grain weight, stover weight and cob weight were significantly higher in the treeless systems. These results corroborate those of [24], who observed maize yields reduced by 35% to 54% in shea-maize systems. We note that despite yield reductions in certain production systems with trees, farmers still keep them in the fields. This shows us the importance of these woody plants in the survival of producers in a context of climate change. Indeed, even if the presence of trees sometimes has a negative impact on the yield of annual crops, many growers say they appreciate them, as they enable them to diversify their sources of income, especially in a context of climate change where annual production is still not certain. Trade in cashew products makes an enormous contribution to improving living conditions. It enables the purchase of fertilizers, labor and schooling for children. For farmers, cashew is a means of adapting to climate change. Indeed, given the great climatic variability of recent years and the vagaries of the seasons, annual crop yields are still not up to expectations.

5. CONCLUSION

The results obtained at the end of this work show that *Anacardium occidentale*, over and above the socio-economic interests that justified its introduction into the Agrarian landscape, it is a species that does not interfere with annual crops. *Anacardium occidentale* can therefore be maintained in the fields to ensure a diversity of production systems in the present context of climate change. What's more, crop yields could be significantly increased by partial or total cutting of the canopy, which would make the most of the species' rich soils under the canopy. Depending on the growers' needs (livestock, crops, energy wood, pharmacopoeia), a compromise must be found in the way *Anacardium occidentale* is managed in the parkland, so as to enable sustainable production through its association with crops. For producers, the adoption of cashew trees in parklands is one of the most widely used strategies for adapting to climate variability.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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