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Full Length Research Paper

Performance of cowpea (*Vigna unguiculata*) and pearl millet (*Pennisetum glaucum*) intercropped under *Parkia biglobosa* in an agroforestry system in Burkina Faso.

Ahmed Nur Osman[1]*, Anders Ræbild[2], Jørgen Lindskrog Christiansen[3] and Jules Bayala[4]

[1]Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen. Motalavej 68, 2th, 4220 Korsør, Denmark.
[2]Center for Forest, Landscape and Planning, Faculty of Life Sciences, University of Copenhagen. Rolighedsvej 23, 1958 Frederiksberg C, Denmark.
[3]Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen, Højbakkegård Allé 30, 2630 Taastrup, Denmark.
[4]Institut de l'Environnement et de Recherches Agricoles (INERA) Burkina Faso, 04 BP 7192 Ouagadougou 04, Burkina Faso.

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In agroforestry systems, crop yields under trees are often low compared to outside. This study explored crop management under trees for improved production and income for farmers. Cowpea (*Vigna unguiculata*) and pearl millet (*Pennisetum glaucum*) sole and intercrops were grown under and outside the shade of six randomly selected *Parkia biglobosa* trees during one season in south-central Burkina Faso. The area under the canopy of each tree was divided into four main plots according to cardinal directions, and sub-divided into three concentric zones. Control plots were established outside the tree canopy. The crops were intercropped in two different proportions using the replacement method and compared to sole crops. Days to flowering were noted and yields were measured, and Land Equivalent Ratio (LER) and Monetary Advantage Index (MAI) calculated. Flowering was earlier outside than under the trees and intercrops flowered earlier than sole crops. Cowpea sole crops had significant grain yield losses of up to 21% under trees compared to outside, and pearl millet yield was reduced up to 67% under trees. Intercrop yields were less affected by growth under trees. LER was significantly higher under the trees than outside, and were always larger than unity indicating benefits of intercropping over sole cropping. Intercropping with two rows of cowpea and one row of millet gave significantly higher economic benefit than mixture with one row of each of the crops. Results indicate that intercropping could improve the system's productivity, increase the income for farmers, and compensate losses in pearl millet under the canopy.

Key words: Intercropping, land equivalent ratio, monetary advantage index, Parkland.

INTRODUCTION

Farmers in the Sahelian and Sudanian zones of Africa are known to maintain parkland agroforestry systems, characterized by the deliberate retention of trees on land cleared for cultivation (Kessler, 1992). To cope with uncertainties associated with crop failures in bad years, these farmers diversify their production. In Burkina Faso, *Parkia biglobosa* (Jacq.) Benth, known as African locust bean in English and as néré in French constitute one of the dominant parkland tree species. Trees are retained on farmlands primarily because of the benefits derived

*Corresponding author. E-mail: anosman@dsr.life.ku.dk

from their fruits (Bayala et al., 2002). Fermented *P. biglobosa* seeds, known as 'soumbala' in Burkina Faso, are widely consumed as a spicy seasoning for sauces complementing cereal dishes (Boffa, 1999). Pearl millet (*Pennisetum glaucum*) and cowpea (*Vigna unguiculata*) are key crops associated with these trees.

Pearl millet is a traditional crop of drier areas and is generally reserved for areas where sorghum and maize fail because of low rainfall and adverse soil factors (Ben Mohamed et al., 2002). Being a drought-tolerant crop, cowpea is adapted to the semi-arid regions of the tropics where other food legumes have poor performance. It is also shade-tolerant and therefore used as an intercrop with maize, pearl millet, sorghum, sugarcane and cotton as well as with several plantation crops (Singh et al., 2003). In normal rainfall years, farmers in Burkina Faso grow drought-resistant varieties of sorghum and pearl millet, sometimes intercropped with cowpea (Roncoli, 2001). Country statistics of food grain prices indicate that cowpea prices have been higher than pearl millet prices for many decades (FAO Country Statistics, 2010). Consumer prices expressed per kg for cowpea ranged 1.5 to 2 times above the prices recorded for pearl millet and sorghum and it was suggested that many households could derive substantial revenues by selling their cowpea and purchase most of the cereal grain needed for their daily consumption (USAID, 2002).

One of the greatest attractions of intercropping is that a yield advantage can usually be achieved simply and cheaply by growing crops together rather than separately, particularly when components are cereals and legumes. Greater resource capture and conversion efficiency of the resource are two ways in which resource use can be improved. Especially intercropping of cereals and legumes give higher yields than sole crops due to higher conversion efficiency of resources (light and water), as under-storey C3 crops are more efficient in conversion of light than cereals (Willey, 1990). Intercropping could also improve water use compared with sole crops by increasing the proportion of evapotransparation which is transpiration. Furthermore legume crops may leave some residual nitrogen for later-maturing crops, or for the following crop (Agboola and Fayemi, 1972).

Understanding the nature of interactions between trees and crops is of major importance in determining approaches to crop management under trees in parklands. In general, there have been a variety of experimental designs as well as control locations which have been used to assess the influence of trees on crop production. Some of these studies are aimed at assessing the negative and positive influences of the presence of *P. biglobosa* in cultivated fields. These influences of trees on crops reported in the literature mainly revolve in shading effects. Plant emergence took place two weeks earlier in tree-adapted species than in plants found outside, while flowering stages started earlier, lasted a shorter time and had a lower success rate in the open than under tree canopies (Akpo and Grouzis, 1993; Boffa, 1999). Duration of the vegetative plant development was longer in sorghum, plant height of both sorghum and pearl millet was negatively affected under *P. biglobosa* canopies and thus maturity was retarded (Kessler, 1992).

Studies from Burkina Faso have revealed that yields of pearl millet and sorghum as sole crops were lower when grown under *P. biglobosa* and *Vitellaria paradoxa* than when grown in the open field. Yields varied with different pruning levels as well as distances from trunk (Kessler, 1992; Bayala et al., 2002). Bayala et al. (2002) reported that crop yield increased after pruning of trees in the short term, while fruiting of trees was delayed two years following pruning. Intercropping of pearl millet with cowpea could be another way of improving the crop production under the trees without increasing input levels. In parkland systems there appears to be no such studies on intercropping. Therefore, this study explored the effect of *P. biglobosa* trees on yield and flowering of pearl millet and cowpea, grown individually and as intercrops. The hypothesis was that intercropping will improve the production of crops under the canopy of trees.

MATERIALS AND METHODS

Study site

The study was conducted in the village of Nobéré (11°30´N, 0°58´W), situated in the province of Zoundweogo in the south-central part of Burkina Faso. The rain falls during a single season from May to October and is characterized by high degree of spatial and temporal variability, with 90% of the total rainfall during July to October (Roncolli et al., 2001). Annual rainfall varies between 800 and 1000 mm (Nikiéma, 2005) whereas the average number of rainy days per year varies between 50 and 80 days (Ministére de l'Economie et Developpement du Burkina Faso, 2005). The rainfall average in Zoundweogo in the post-1969 period (723 mm) was drastically lower than the average between 1949 and 1969 (910 mm) (Boffa et al., 2000). The average temperature ranges around 30°C; the warmest months are March and April, during which average temperatures can be above 38°C. The natural vegetation (and non-cultivated area or fallowed fields) are savannas with a continuous herb layer and a more or less continuous layer of trees and shrubs (Ministére de l'Economie et Developpement du Burkina Faso, 2005).

The soil of the study area is a luvisol with a sandy loam texture (clay = 11.5%, silt = 20.1% and sand = 68.4%) with low nutrient content (N = 0.69 g / kg, P = 0.14 g / kg and K = 0.50 g / kg), low organic matter content (1.32%) in the uppermost 10 cm of soil and thus poor water holding capacity. The vast majority of the population in south-central Burkina Faso depends on agriculture for its livelihood, 85% being engaged in farming as the main livelihood strategy (Ministére de l'Economie et Developpement du Burkina Faso, 2005). In Nobéré, major subsistence crops are pearl millet, sorghum (white and red), peanuts and cowpea. The two latter are the only legume field crops grown in Nobéré. Animal husbandry of mainly cattle and goats represents the second most important economic activity in the area (Augusseau et al., 2006). In 2007 when the trial was conducted the precipitation in Nobéré was relatively high with a total precipitation of 978 mm and 59 rain days (Figure 1). Despite a few scattered showers in Nobéré between

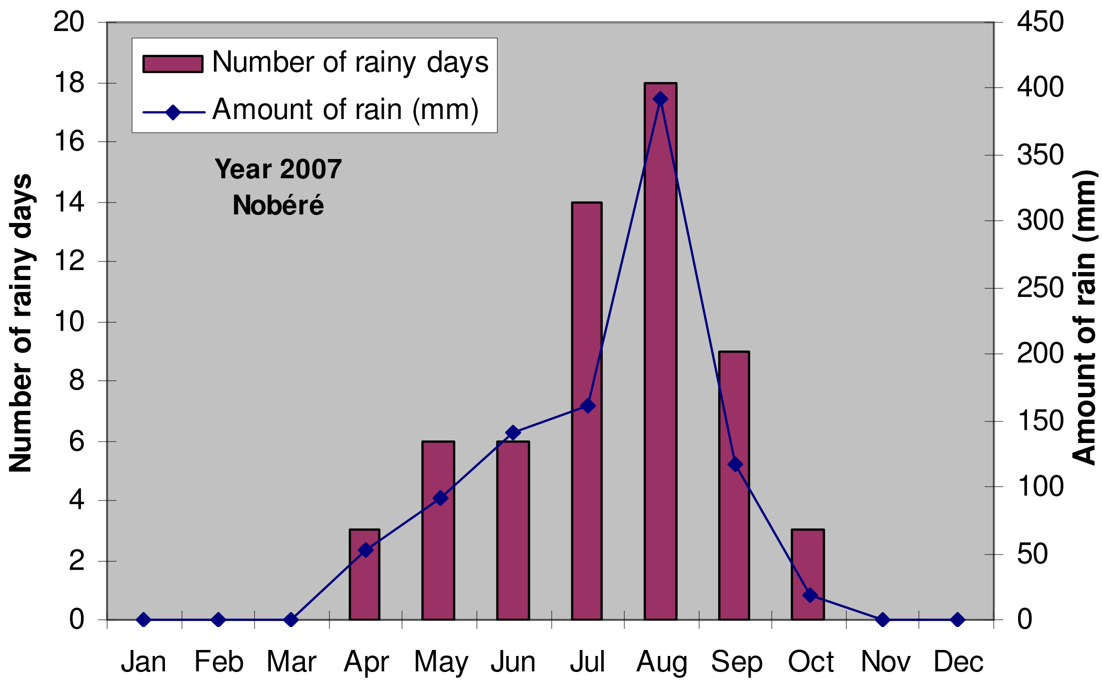

Figure 1. The amount of rain and number of rainy days in Nobéré in the year 2007 (Rain data from Ministere de l'Agriculture, de l'Hydraulique et des Resourcces Halieutiques. Secretariat General. Direction Regionale du Centre-Sud.)

Table 1. Description of the six *P. biglobosa* trees selected for the experiment.

Tree no.	Height (m)	Trunk diameter at breast height (cm)	Tree crown average radius (m)	Estimated tree crown projection area (m^2)
1	10.3	94	8.0	201
2	15.5	88	10.0	313
3	10.0	60	9.6	286
4	10.2	58	8.0	199
5	12.0	84	11.4	407
6	11.3	68	8.5	228
Average	10.8	75	9.2	272

April and June there were no large rains until late June and early July. Farmers in the region call these small and short showers locally as sigri saaga which means false rains or small rains. There were thus many different sowing dates in Nobéré between May to July as farmers differed in their risk aversion.

Tree material

Six unpruned *P. biglobosa* trees were selected for the experiment. Trees were situated away from shade of any surrounding tree, and the fields under the selected tree had been left fallow for at least two years prior to the experiment. According to the owners, fields under the trees had previously been cultivated with pearl millet, sorghum, and maize. All the trees were located in a 1 km^2 area 7.2 km to the west of Nobéré (11°31´ N to 1°13.05´ W and 11°30´ N to 1°13.39´W). Table 1 gives a description of the trees.

Crop and soil management

Genetically unimproved farmers seeds of local varieties of pearl millet (*P. glaucum*) and cowpea (*V. unguiculata*) were used for this experiment, cowpea being the creeping type. Seed selection and cultural practices were based on a preliminary survey interview with 30 farmers in order to adopt the low input farming practice prevailing in the village. All plots were ploughed using oxen-pulled plough, and spacing of 60 x 60 cm was done with a hand-pulled local tool. Because the creeping type of cowpea is an obstacle for the bull-dragged cultivator, farmers in the village use the relatively wide spacing of 60 x 60 cm in all field crops. Thereby it is possible to perform inter-row cultivation two times in the growing season before cowpea rows grow to close the space. This technique was also adopted in this experiment. Both crops were sown on July 18 2007 at a seed rate of ten seeds per hill for pearl millet and two seeds per hill for cowpea, and hand seeding was adopted.

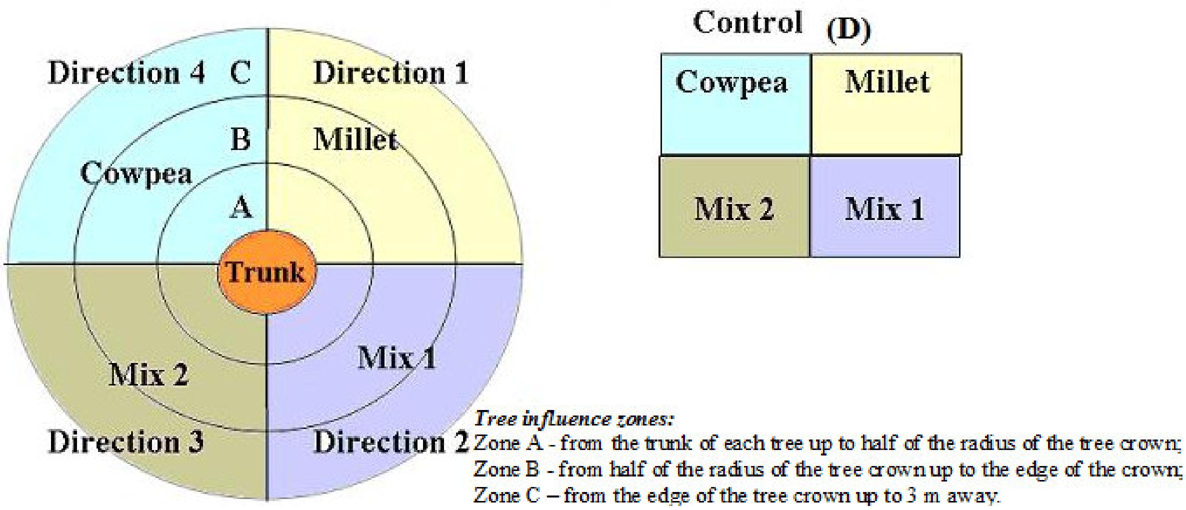

Figure 2. Split-plot design for comparing cowpea and pearl millet sole-crops and intercrops under the shade of *P. biglobosa*.

Plant density for each sole crop was 36,000 plants per hectare while intercrop densities were proportions of the sole-crops, an intercropping method referred to as ‘replacement’ method (Natarajan and Willey, 1986). There were two levels of intercropping in the experiment. In the first mixture (MIX 1), one row of pure pearl millet was intercropped with one row of cowpea, representing a proportion of 0.5 for each crop. In the second mixture, one row of pearl millet was intercropped by two rows of cowpea, representing proportions of 0.67 for cowpea and 0.33 for pearl millet. At maturity of crops, 2.4 x 2.4 = 5.76 m^2 area was harvested from each plot. Cowpea was harvested on 21st of October while pearl millet was harvested on 25th of December. The parkland agro-forestry system in the village of the study is a low input and rainfed system where poor farmers do not fertilize their fields. The experiment was set in such a way that the obtained yields should be realistic and represents the amounts obtained by poor farmers.

Therefore, fertilizers and other soil amendments were not applied on the experimental plots. Oxen-dragged cultivator was used to plough the soil at the seedbed preparation and also at first weeding. For the second weeding manual hand hoeing was used.

Experimental design

A split-plot design was established under the canopies of the selected *P. biglobosa* trees (Figure 2). The area under each tree was divided into four main plots of equal size according to the cardinal directions. Three concentric zones (tree influence zones) constituted sub-plots in the design. The two sole crops (pearl millet and cowpea) and their two intercrops (MIX1 and MIX 2) were assigned randomly to the main plots. Moreover, control plots for each of the four cropping systems were established outside the shade of any tree in the field. The size of each control plot was 16 m^2. The six trees were randomly selected from the cultivated parkland forest and, thus, represented replicates or blocks.

Flowering, grain yield, Land equivalent ratio (LER) and Monetary advantage index (MAI)

The number of days elapsed between crop planting to the days of flowering, and the number of days to emergence of spikes were noted. Each subplot was observed and the date was noted when 40% of plants within an individual sub-plot and control plot flowered/developed spikes. These observations took place daily. Within each subplot, an area of 2.4 x 2.4 = 5.76 m^2 was harvested at crop maturity. Harvested material was threshed for each subplot separately and weighed. Land Equivalent Ratio (LER) was calculated to determine whether intercropping was more beneficial to farmers than cultivation of sole-crops. LER, as defined by Willey and Osiru (1972), is the total land area required for single crops to give the yields obtained in the intercropping mixture:

$$LER = LER_C + LER_M \quad (1)$$

$$LER_C = \frac{Y_{iC}}{Y_{sC}} \quad (2)$$

$$LER_M = \frac{Y_{iM}}{Y_{sM}} \quad (3)$$

Where the subscript letters, *C* and *M,* stand for cowpea and pearl millet, respectively; Y_{iC} and Y_{sC} are yields of cowpea intercrop and solecrop, while Y_{iM} and Y_{sM} represent yields of pearl millet intercrop and solecrop. The critical value of LER is unity, that is a LER value above one indicates an advantage of intercropping over sole cropping while LER values below one shows that there is no advantage by intercropping.

Yields of the intercrop components can be converted to money value by multiplying the price of each crop to its yield and add the values of the two different crops to be the combined values of the intercrops. The method is called the Monetary Advantage Index (MAI) and is based on crop prices and LER:

$$MAI = \frac{((value\ of\ combined\ intercropping) \times (LER - 1))}{LER} \quad (4)$$

Table 2. Average prices per kg of pearl millet and cowpea in the village market.

Crops	Price per kg in the local currency F CFA	Price per kg in USD exchange rate : 1USD = 414.611 F CFA
Cowpea	283	0.68
Pearl millet	158	0.38

This calculation assumes that the appropriate economic assessment of intercropping should be in terms of increased value per unit area of land (Willey, 1979). The higher the MAI value the more profitable is the cropping system (Ghosh, 2004). The calculations of MAI were based on prices of the two crops obtained through frequent visits of the village market in the year 2007 and price data in previous years recorded by the agricultural extension office in the village (Table 2).

Statistical analysis

All data were processed using R-2.6.2 statistical software, using a Gaussian mixed linear model to analyze days to crop flowering, yield, LER and MAI. The following model was used for the analysis of yield and flowering/spike emergence of each crop type:

$$Y_{ijk} = \mu + \alpha(cardinal\ direction_i) + \beta(zone_j) + d(tree_k) + \varepsilon_{ijk} \quad (5)$$

Where $d(k) \sim N(0, \sigma^2_{tree})$, $\varepsilon_{ijk} \sim N(0,\sigma^2)$ and all $d(k)$'s and ε_{ijk} 's are independent.

For the analyses of LER and MAI, a crop factor and Zone × Crop interactions were included in the fixed part of the model. Thus, the model is:

$$Y_{ijkl} = \mu + \alpha(cardinal\ direction_i) + \beta(zone_j) + \delta(crop_k) + \theta(zone_j{*}crop_k) + d(tree_l) + \varepsilon_{ijkl} \quad (6)$$

The full models were fitted using the maximum likelihood (ML) method for analysis of variance. Model validation was carried out by analysis of residual plots, and in cases where residuals showed patterns, data were transformed to reduce variation. The models were then reduced by removing non significant effects one by one followed by testing the significance of the reductions (Martinussen et al., 2007). Cardinal direction was significant in none of the models and will not be referred to later. For days to flowering and yield, the resulting model was:

$$Y_{ij} = \mu + \beta(zone_i) + d(tree_j) + \varepsilon_{ij} \quad (7)$$

Whereas for LER the model was:

$$Y_{ij} = \mu + \beta(zone_i) + d(tree_j) + \varepsilon_{ij}$$

For MAI, the resulting model was:

$$Y_{ij} = \mu + \delta(crop_i) + d(tree_j) + \varepsilon_{ij}$$

The reduced models were used to calculate significances for the included factors together with their 95% confidence intervals. For data transformed with the natural logarithm, confidence intervals were calculated in the logarithmic scale and back transformed with the exponential function. Therefore, bar plots for transformed response variables show the geometric means. A summary table showing P values, significant factors and scale of the analyzed data (whether original or logarithmic) is supplemented to the bar plots.

RESULTS AND DISCUSSION

The variations between experimental units were high and overall yield figures obtained in this experiment were extremely low. Low yields were more pronounced in pearl millet. These low yields and associated variations can be mainly attributed to year. Although the year of the study 2007 had a high precipitation of 978 mm, the few torrential rainy days were accumulated between July and August, and by the end of September the soil started to dry out due to high temperatures. Moreover, there were only three rainy days with small amounts of precipitation in October. Cowpea which was harvested on 21st of October was not relatively much affected by water stress but pearl millet which was not harvested until 25th of December gave lower yields.

Year effects could have been captured if this study had been repeated in several years. Whelan and McBratney (2000) observed that coefficients of variation of yield ranged from 13 to 83 % for wheat and from 12 to 44% for sorghum in two consecutive years. Porter et al. (1998) reported coefficients of variation from field plots for corn and soybean yields ranging from 2 to 19% over 10 studied years.

Days to flowering and spike emergence

Cowpea flowering was significantly affected by *P. biglobosa* in all cropping systems (solecrop, MIX 1 and MIX 2) (Table 3). Flowering of cowpea was up to one week delayed in zones closer to the trunk of the tree compared to the control plot beyond the canopy reach (D) (Figure 3). Similar patterns of responses were observed in the three cropping systems. Spike emergence of pearl millet showed a similar response in all cropping systems and was significantly affected by distance to tree trunk (Table 3). Spikes emerged earlier with increasing distance from the tree trunk (2.8) (Figures 4 a to c), the average difference being up to 10 days between control plots and plots closest to the tree trunk. The results in this study are similar to results (2.9) reported by Akpo and Grouzis (1993) and Boffa (1999) finding earlier flowering of plants outside the tree than under the tree.

Grain yield

Cowpea mean yields in the intercropped systems were generally lower than in the sole crop as a result of the

Table 3. Table of significance for grain yield of cowpea and pearl millet sole crops and intercrops, and MAI in response to cropping systems and distance (zone) from the tree trunk.

Parameters and Cropping systems	Scale		Treatments		Significance
	Original	Logarithmic	Crop	Zone	p-value
Days to flowering for cowpea					
Sole crop	X			X	0.0001
Intercrop (MIX 1)	X			X	0.0003
Intercrop (MIX 2)	X			X	0.0001
Days to spike emergence for millet					
Sole crop	X			X	0.0001
Intercrop (MIX 1)	X			X	0.0001
Intercrop (MIX 2)	X			X	0.0001
Cowpea grain yield					
Sole crop	X			X	0.0001
Intercrop (MIX 1)	X			X	0.0002
Intercrop (MIX 2)	X			X	0.0001
Millet grain yield					
Sole crop		X		X	0.0681
Intercrop (MIX 1)		X		X	0.2898
Intercrop (MIX 2)		X		X	0.382
Land Equivalent Ratio (LER)		X		X	0,0399
Monetary Advantage Index (MAI)					
Sole crop	NA	NA	NA	NA	NA
Intercrop (MIX 1)	X		X		0.0001
Intercrop (MIX 2)	X		X		0.028

higher plant population in the sole crops than intercrop (Figure 5). As such, comparison between sole crop and intercrop yields is not valid by direct comparison of mean yields. In this study, the method of Land Equivalent Ratio (LER) for comparing sole crop and intercrop yields is used and, therefore, relative yields are compared. Cowpea productivity was negatively affected when the crop was grown under trees. Yield reductions of 21.2, 12.5 and 3.4% were observed for sole-cropped cowpea in zone A, B, and C, respectively, compared to control plots outside the canopy. In the intercrops, yield reductions were less pronounced, amounting to 11.3, 6.7 and 4.5% for A, B and C in MIX 1, and 14.6, 9.8 and 4.7%, for zones A, B, C in MIX 2.

Results presented here are in line with results obtained in other C_3 crops. Louppe (1993) found that yields of groundnuts and cotton were severely depressed, (-20 and -32%, respectively) under *V. paradoxa* on low fertility soils. Variations in intercropped cowpea grain yield are lower than those of cowpea sole crop. These high variations in sole crop cowpea can be due to intra species competition of the creeping type of cowpea in sunlight and other resources. Similarly, the lower variations in the intercropped cowpea can be attributed to lower population of cowpea in the intercrop and wide spacing of rows and plants which minimized intra crop competition. This result is agreement with Azam-Ali and Squire (1993) who reported that intra (that is within) species competition in intercropping usually proceeds inter (that is between) species with regards to competition for light.

Sole-cropped pearl millet yields under the tree were 58, 60 and 75 kg/ha for zones A, B, and C respectively, while in the control plot (D) yield was 174 kg/ha. These differences in yield were not statistically significant though the p-value was 0.07, close to being significant.

Similarly, intercrop yields of pearl millet were not significantly affected by distance from the tree trunk (Figures 6a to c, Table 3). Kessler (1992) observed a 70% decrease of pearl millet yield towards the trunk compared to outside, but this does not always apply (Boffa, 1999). For example another study from Burkina Faso found no significant differences in pearl millet grain production growing under *V. paradoxa* and *P. biglobosa*

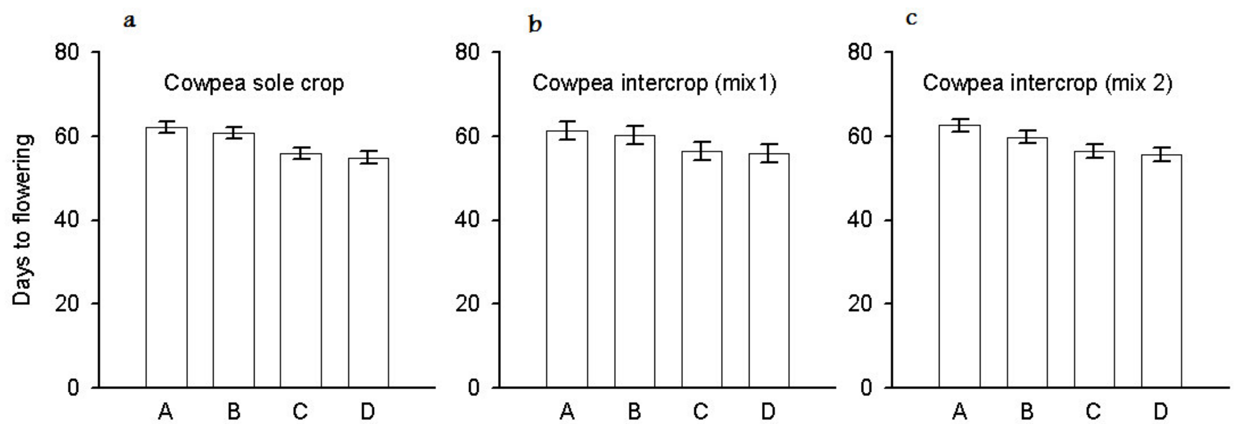

Figure 3. Days to flowering of cowpea sole crops and intercrops (a-c) in response to distance from the tree trunk (zone A (closest to trunk), B, C and D (control plot)). Error bars represent 0.95 level of confidence.

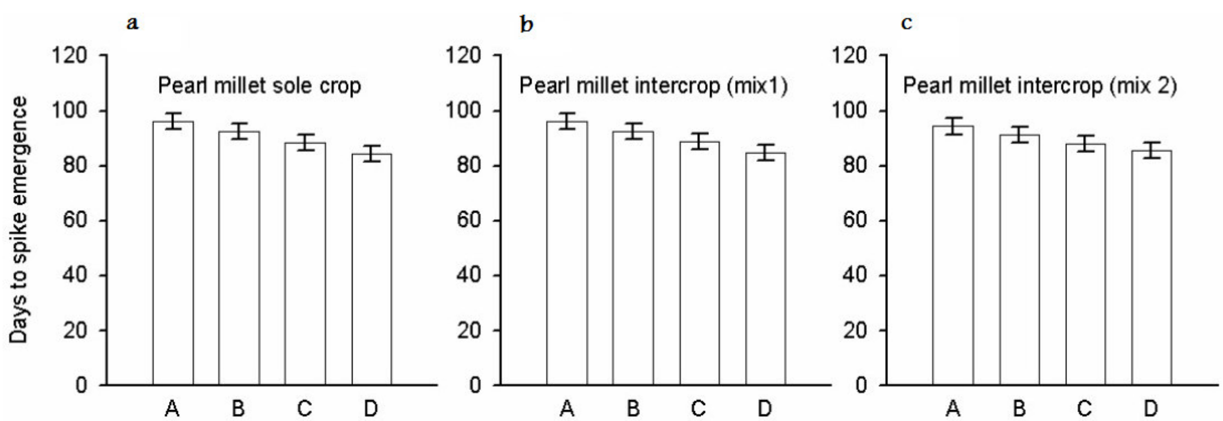

Figure 4. Days to spike emergence of pearl millet sole crops and intercrops (a-c) in response to distance from the tree trunk (zone A (closest to trunk), B, C and D (control plot)).. Error bars represent 0.95 level of confidence.

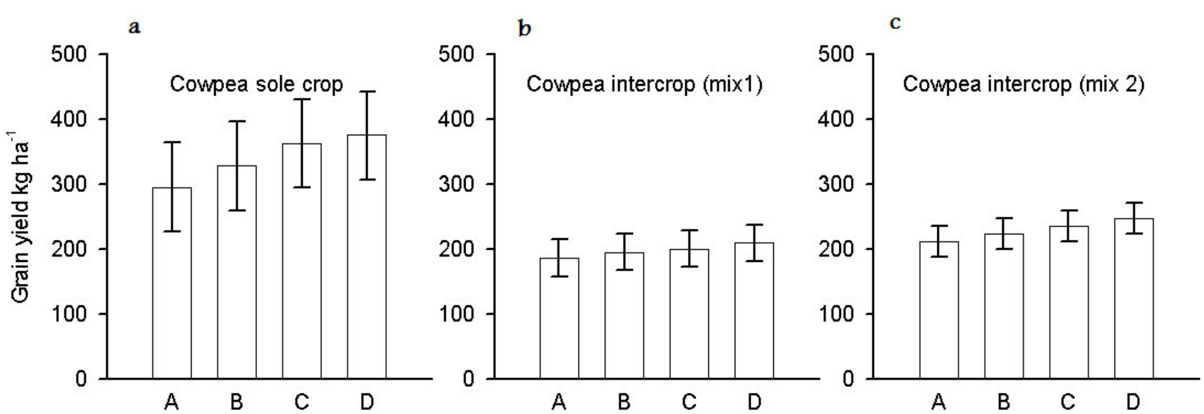

Figure 5. Grain yields of cowpea sole-crop and intercrop (a-c) in response to distance from the tree trunk (zone A (closest to trunk), B, C and D (control plot)). Error bars represent 95% confidence intervals.

canopies and in the open in a year of higher than average rainfall (Jonsson, 1995). The high variability of millet yield is consistent with Rockstrom and de Rouw (1997), who observed higher variability in millet yield in

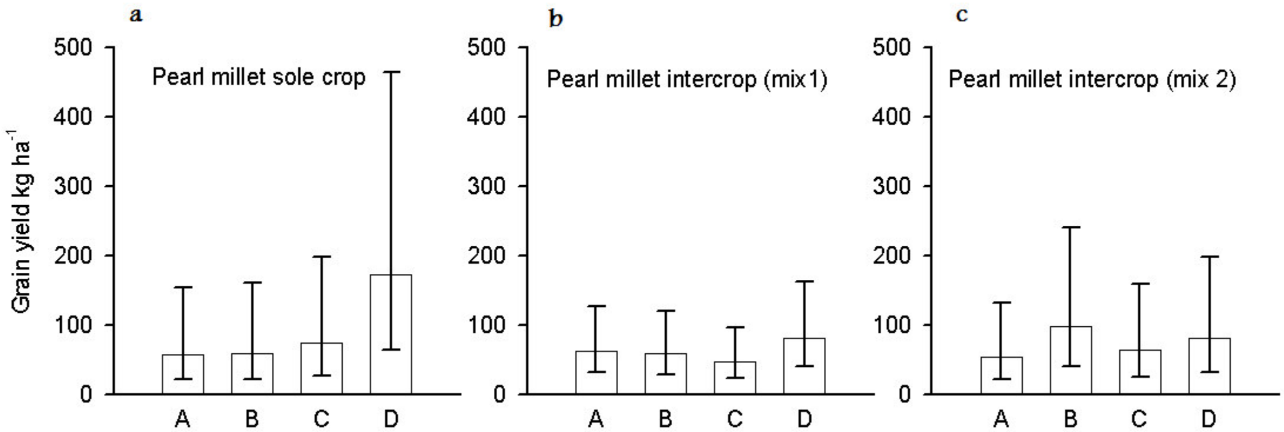

Figure 6. Grain yields of pearl millet sole-crop and intercrop (a-c) in response to distance from the tree trunk (zone A. B. C and D (control plot)). Error bars represent 95% confidence intervals.

nonfertilized compared with fertilized treatments under water-stressed conditions in the Sahel. Similarly, Kravchenko et al. (2005) found that coefficients of variation for maize and sorghum were as high as 45% in years with low precipitation compared to 14% in years with above-average precipitation.

These yield reductions and delayed flowering are mainly attributable to presence of trees. Trees reduce the amount of sunlight reaching soils and crops through shading (Boffa, 1999) with successively less shading further away from the trunk (Kessler, 1992). Yield components are mutually dependent, and variables measured and reported in the various studies differ so that the effect of the of shade of trees on specific yield components is more difficult to determine and it is also likely to vary locally (Boffa, 1999) but grain yields are generally lowest next to the trunk of the tree and gradually improve with increasing distance from the trunk (Kessler, 1992).

The focus of this study was to determine the effect of shade on crops. The effects of particular tree parameters such as height and crown diameter on crops were not the focus of this study. Trees in their different sizes were randomly selected from the parkland forest and used as replicates or blocks.

Land equivalent ratio (LER) and Monetary advantage index (MAI)

The land equivalent ratio of cowpea and pearl millet intercropping was found to be significantly affected by distance from the trunk of *P. biglobosa.* The p-value was 0.04 when data were analyzed in logarithmic scale (Figure 7 and Table 3). LER values were significantly higher than one in all distances from the tree trunk (A, B and C), revealing that intercropping was more productive than sole-cropping. The LER values outside the canopy were also significantly lower than under the tree canopy. LER values for zone A, B and C were found to be 1.80, 1.89 and 1.55, respectively, while in the control plot it was lowest with a value of 1.22. Differences in LER values between the mixed cropping systems were not significant. Thus, intercropping was found to be more advantageous in zones where yields were more depressed, particularly the zones A and B.

Willey (1990) also reported that intercropping of cereals with legume grain crops gave higher yields than sole-cropping as indicated by LER values. The underlying principle of better resource use in intercropping is that if crops differ in the way they utilize environmental resources they can complement each other and make better combined use of resources when grown together than when they are grown separately. LER gives an accurate estimate of the greater biological efficiency of the intercropping situation (Ghosh, 2004) and, thus, an estimate of the land use advantage. Higher LER values observed in zones were sole crop yields are more depressed is due to the fact that LER is an index which is based on yield ratios of crops and, therefore, is sensitive to the divisor, that is, the yields of sole crops (Francis, 1986). The lower the sole crop yield (the divisor) the higher the LER value. MIX 2 had a significantly higher MAI value than MIX 1 (Figure 6 and Table 3) indicating higher economic advantage of MIX 2 cropping system than MIX 1. Zone had no significant effect on the MAI. The difference between the two intercrops in MAI is due to the higher proportion of cowpea in MIX 2 than MIX 1 and the higher prices of cowpea than that of pearl millet.

This study, pointing to an advantage of intercropping, was realized during only one season and it is possible that results would differ in other years where conditions were different. One of the disadvantages of intercropping of cowpea with pearl millet could be higher labor inputs required during the inter-row cultivation of pearl millet for weed control. The creeping type of cowpea grown

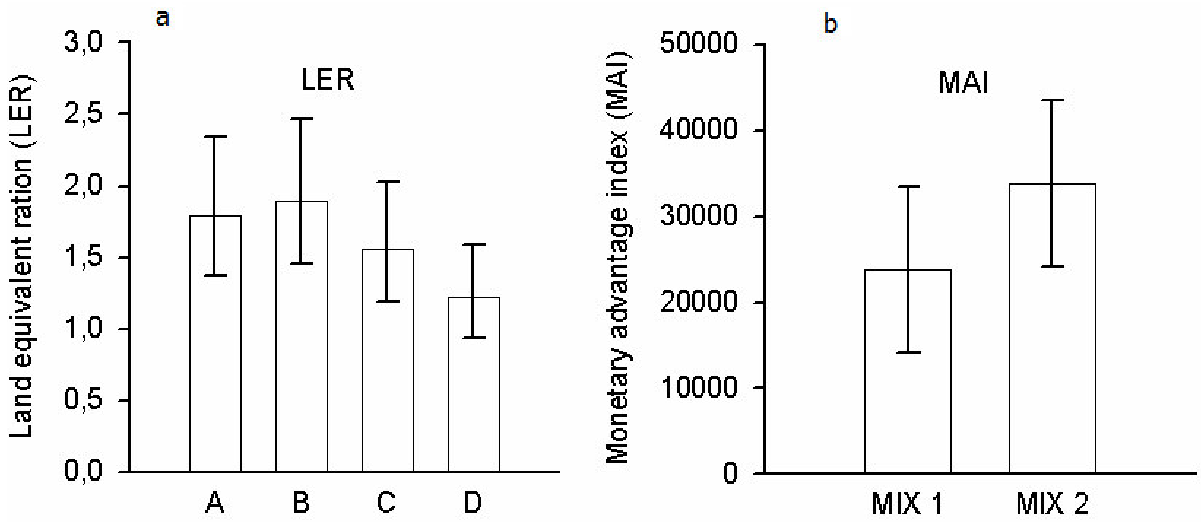

Figure 7. (a) Land Equivalent Ratio (LER) for cowpea and pearl millet intercropping as affected by distance from the trunk of *P. biglobosa* (Zones A. B. C and D-control plot). (b) Monetary Advantage Index (MAI) for two intercropping levels (MIX 1 and MIX 2) of cowpea and pearl millet. Error bars represent 0.95 level of confidence.

between pearl millet rows is an obstacle to the bull-dragged cultivator used in the village of this study. Thus, the farmers may have to resort to hand-hoeing thereby increasing labor input. Moreover, cowpea plants are harvested earlier when pearl millet plants are too short and before emergence of spikes. Further investigations comparing labor requirement of the two crops would be necessary to clarify this. The study certainly points to the need for further investigation of intercropping as a means to increase productivity of agroforestry parklands.

In this respect, two research questions could be: 1. Will intercropping of legume and cereal crops generally result in higher yields in agroforestry parklands? 2. Is intercropping consistently more advantageous under trees than outside?

Conclusion

P. biglobosa had negative effects on yields and flowering of cowpea and pearl millet sole crops but their intercropping under and outside the canopy of the tree improved yields. Cowpea yields were less reduced under trees than millet yields. The advantage of intercropping was higher where sole crop yields were more depressed particularly zones immediate to trunk of the tree. The economic advantage per unit area of land was higher when cowpea proportion in the inter-cropping was set to 0.67. The results of this study thus confirm that intercropping in some cases is more productive than sole crops, and that this effect is even more pronounced under trees. However, results from one single year cannot be generalized, and the experiment should be repeated during more seasons and at other sites before recommendations can be made.

Furthermore, it should be realized that farmers do not change their cropping system just for the sake of high yield or future soil fertility improvement. Farmers' choice of crops is determined by factors including labour availability, family needs, inputs, and availability of market. Whether farmers in Nobéré would benefit from inter-cropping thus not only depends on the repeatability of results in this paper but also by farmers' perception of their own situation.

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