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Effect of *Azadirachta indica A.* Juss (Neem) on the Growth, Physiology and Yields of Associated Crops in Agroecosystems in the Sudano-Sahelian Zone of Burkina Faso, West Africa

Boukary Soro [a*], Hugues Roméo Bazié [a], Paulin Bazié [b], Boblwendé Gildas Flavien Sawadogo [a], Sotongo Abraham Ouédraogo [a] and Gérard Zombré [a]

[a] Plant Ecophysiology Research Team, Biosciences Laboratory, Life and Earth Sciences Training and Research Unit, Joseph Ki-Zerbo University (UJKZ), 03 BP 7021 Ouagadougou 03, Burkina Faso.
[b] Environment and Forestry Department, Institute for the Environment and Agricultural Research (INERA), 03 BP 7047 Ouagadougou 03, Burkina Faso.

Authors' contributions

This work was carried out in collaboration among all authors. Authors BS and HRB conceptualized the study, did funding acquisition, formal analysis, investigation, performed the methodology, did Software, data visualization, wrote and prepared the original draft of the manuscript. Author BS did data curation. Author PB performed the methodology, reviewed and edited the manuscript. Authors SAO and BGFS did investigation, data curation, reviewed and edited the manuscript. Author GZ reviewed and edited the manuscript. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: soroboukary@outlook.fr;*

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Original Research Article

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ABSTRACT

Neem is an exotic species used for reforestation, but its competitive effects on surrounding crops have not been thoroughly explored in Burkina Faso. This research aimed to assess the effect of neem on cowpea, millet, and sorghum within agroecosystems in Burkina Faso. The experimental design involved systematically allocating treatments based on the gradient of the tree's effects, with three replicates of each crop, totalling nine neem trees. The treatments concerned three plots located based on their distance from the isolated neem trunk: one plot was situated directly under the crown, another was 11 m away from the trunk, and the third was 22 m away. Key parameters, such as stem length, crop leaf area index, photosynthetically active radiation, linear electron flux, grain and straw yields, were measured. Results indicated that fall crops, stem length, photosynthetically active radiation, linear electron flux, and crop leaf area index were significantly lower under the neem crown compared to areas outside the crown ($P<0.05$). For instance, the photosynthetically active radiation was significantly lower in plots situated directly under the crown compared to plots outside the crown at 22 m from the trunk, across all crops ($P<0.05$). Additionally, grain and straw yields were significantly reduced under the neem crown compared to the border and areas outside the crown for all crops studied ($P<0.05$). These findings suggest that neem has detrimental effects on intercropping within agroecosystems.

Keywords: Competition; neem; shade; millet; cowpea; sorghum.

1. INTRODUCTION

Azadirachta indica A. Juss, commonly known as neem, is an exotic species from India that has been introduced to our country (Bationo et al., 2004). Its remarkable ability to adapt to challenging pedoclimatic conditions makes it a key species for reforestation initiatives aimed at mitigating land degradation and deforestation (Diedhiou, 2017). Farmers have increasingly recognized the potential of this species to provide timber, leading to its promotion and integration into agroecosystems. For instance, Chittapur and Gurumurthy (2018) reported that high soil microbial density was observed in areas near neem trees. Moreover, research by Honnayya (2024) and Oyinlola (2017) showed that the availability of essential nutrients, particularly nitrogen, phosphorus, and potassium, was higher near neem trees compared to areas farther away. A survey conducted by Bationo et al. (2004) in Burkina Faso revealed that 90% of farmers interviewed noted rapid decomposition of neem leaves, which enriches the soil underneath the trees. Additionally, microdosing of neem cake has been shown to enhance grain yields for maize (Traore et al., 2019). However, some authors research indicates adverse effects of neem on neighbouring crops. A study by Bello et al. (2023) in Nigeria, had identified neem as an invasive species that often outcompetes. Other studies have reported decreased growth and yield in certain cereals, such as pigeon pea when grown near neem trees (Chittapur and Gurumurthy, 2018; Honnayya, 2024) and sorghum (Yelemou, 1993). Thus, while the presence of neem in agroecosystems can enhance soil composition, the growth and yield of surrounding crops tend to decline as its proximity to the neem tree increases. Introduced to our country a few years ago, neem has rapidly spread across the agricultural landscape due to its natural propagation by seed and adaptability to various soil types (Ganaba, 1996). It is intentionally kept in fields for a variety of socio-economic reasons (Yougma, 1994). In these agroecosystems, farmers appreciate the impact of neem on annual crops to varying degrees (Bationo et al., 2004). Additionally, the interactions between neem and the associated crops have not been extensively studied, leading to conflicting opinions that are sometimes based on prejudice rather than research. Understanding the nature and extent of neem's competitive influence on surrounding crops is essential to developing effective management strategies, ultimately enhancing agricultural productivity in areas where neem is increasingly establishing itself. Hence, this study aims to assess the influence of neem on the growth, physiology, and yield of three cereals: cowpea, sorghum, and millet within the agroecosystems of Burkina Faso.

2. MATERIAL AND METHODS

2.1 Study Site

This study was conducted in fields located in Gonsé village, in the municipality of Saaba, Kadiogo province (12°25' north latitude, 1°20' west longitude), at an average altitude of 200 m. This site belongs to the Sudano-Sahelian climatic zone, characterized by two seasons such as a rainy season from May to October and a dry season from November to April. The total annual rainfall for the 2022 to 2023 rainy season was 816.5 mm. During this period, August was notably the wettest month, receiving 248.6 mm of rainfall. The minimum temperature was 25.6°C in January, the maximum was 33.7°C in April, and the average temperature was 29.79°C (National Meteorological Agency of Burkina Faso). Edaphically, the soils of Gonsé are classified as tropical ferruginous with variable characteristics, predominantly sandy-clay or gravelly (BUNASOLS, 1990).

2.2 Plant Material and Selection of Trees

The plant material consists of the following crops: cowpea, millet, and sorghum. These three crops were chosen because they are the main crops produced and used for food and fodder for animals in our study area. These crops are well adapted to local climate conditions and possess a degree of tolerance to drought and *Striga sp*. Regarding neem, nine individual trees of this species were randomly selected from local farms based on specific criteria, including their health, crown diameter, and a requirement of at least 40 m away from other trees of the same species. The average crown diameters of the selected trees were evaluated to 10.92 ± 1.48 m in the East-West direction and 11.62 ± 1.79 m in the North-South direction. The stem diameter was measured at a height of 1.30 m, ranging from 1.1 ± 0.17 m to 1.65 ± 0.17 m, with an average of 1.30 ± 0.17 m.

2.3 Experimental Design

The experimental design employed is based on a systematic allocation of treatments due to the tree effect gradient, known as a gradient-based design (Bayala et al., 2015), with three replicates. Nine neem trees were chosen and divided among three plants for each crop type. These neem trees were randomly distributed across the fields. Each neem tree functioned as a replicate and was linked to three square plots of 100 m² (10 m x 10 m), leading to a total of 27 elementary plots. Arrangements for the plots associated with each neem tree were as follows: one plot was located directly under the crown of the neem plant, referred to as PUC. The second plot was centred at 11 m from the neem trunk, labelled as POC11. The third plot was centred at 22 m from the neem trunk labelled as POC22, serving as the control plot. Each plot is separated from its neighbouring plots by 1 m (Fig. 1). To minimize the effects of morning or evening shadows, a transect approach was used, following a north-south direction (Bayala et al., 2015). The control plot was chosen so that it would not be shaded by other woody plants or by the neem tree, the subject of our study, at any time of day, which resulted in some plots being slightly misaligned from the ideal north-south.

2.4 Experiment Setup and Data Collection

After a rainfall of at least 20 mm, the plots were ridge-ploughed using animal traction. Sowing of selected crops took place on July 23, 2023. For millet and sorghum, the row spacing was 0.8 m and the spacing between sowing holes was 0.6 m. For cowpea, the spacing between sowing holes was 0.6 m, and the spacing between rows was also 0.8 m, with 0.4 m between sowing holes. Three to four seeds of each crop were sown in each hole. Between 15 and 20 days after emergence, a thinning was performed to leave only two plants per hole, two weeks after emergence. Two manual weeding operations were conducted, the first between 15 and 20 days after emergence and the second three weeks after the first. In each plot, five plants of the crop were selected and marked along the diagonals for monitoring and measuring various parameters. On these selected plants, the stem length was measured using a meter tape. Physiological parameters were focused on the third leaf from the top of each selected plant.

Leaf area index (LAI) was measured using an AccuPAR PL-80 ceptometer. The measurements were conducted between 10 a.m. and 2 p.m. on clear days. Due to the distance between the fields, it was not feasible to complete all LAI measurements before sunset; thus, measurements were restricted to plots PUC and POC22. For the measurements, the ceptometer was placed near the base of the selected crop plant, where the device automatically calculates the LAI based on the crown of the plant. The approach for measuring LAI under the crown was executed in two phases. Initially, we measured the LAI of the neem tree, followed by the LAI of the crops that were growing beneath its crown. The ceptometer recorded the total leaf area index for both neem and the under-crown crops. Subsequently, we measured only the leaf area index neem. Ultimately, to determine the leaf area index of the crops growing under the crown, we subtracted the neem individual leaf area index from the total recorded LAI. LAI values were determined by considering the average of values from five individuals at different probe positions, both parallel and perpendicular to the crop rows. To minimize the impact of leaf movement, two measurements were taken at each position.

2.5 Measurement of Photosynthetically Active Radiation and Linear Electron Flux

The photosynthetic activity parameters of three crops were measured using the PhotosynQ MultispeQ (MultispeQ V2.0). This device helped to assess the influence of neem on various key parameters, such as photosynthetically active radiation and linear electron flux (Kuhlgert et al., 2016). Measurements were consistently taken from the third leaf from the top of the stem on five plants each of sorghum, millet, and cowpea in every plot. Measurements were taken once between 12 p.m. and 2 p.m.

2.6 Yield Evaluation

A complete harvest was carried out at the end of each crop growth cycle in each plot to assess yield parameters. Harvested pods, ears and panicles were air-dried and weighed before being threshed and winnowed to extract the grains. Stems were cut at the collar, collected in piles, and dried before being weighed. To determine yields, the dry masses obtained on each plot were converted into kilograms per hectare (kg/ha).

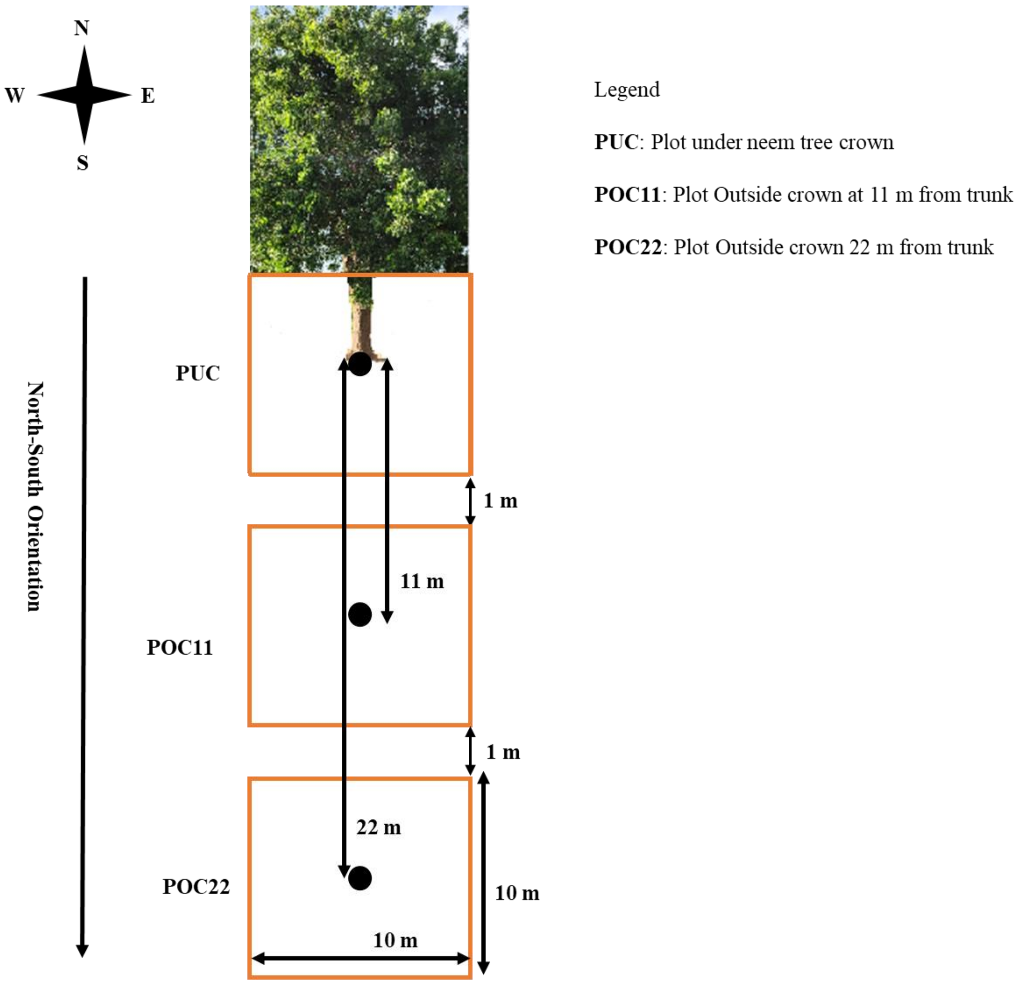

Fig. 1. Experimental design

2.7 Data Processing and Analysis

Data were recorded using Excel spreadsheets. For physiological parameters, measured data on five plants per plot were used to calculate the mean of the plot, which represented the overall condition of each plot. Each crop was treated as a separate experiment, so no comparisons were made between different crops. All data were analysed using R software version 4.3.0, taking into account the distance factor (PUC, POC11, POC22) of the plots from the neem trunk. In the experimental design of this study, the location of plots according to their distance from the neem trunk was not entirely random, which complicated the randomization process. According to Bayala et al. (2015), Sanou (2010), and Wilson et al. (1998), the systematic arrangement of plots complicates the determination of a valid error estimate, as neighbouring plots may present correlated residuals. Indeed, a pairwise comparison using a 5% threshold t-test was used to determine the variance of the data as a function of distance from the neem trunk.

3. RESULTS

3.1 Effect of Neem on the Stem Length and Leaf Area Index of Associated Crops

The study examined three crop types and found significant differences in stem lengths through pairwise comparison t-tests. The results indicated significant differences between POC22 and PUC, POC11 and PUC, and POC22 and POC11 (*P<0,05*) (Table 1), except between POC11 and POC22 for sorghum (*P=0.12*). In terms of the leaf area index (LAI), significant differences were noted specifically between POC22 and PUC for cowpea (*P=0.01*) and millet (*P=0.04*), while sorghum did not show significant variation (*P=0.06*) (Table 1). Cowpea main stem heights were 53.07±7.88 cm; 87.27±7.66 cm, and 121±7.21 cm for PUC, POC11, and POC22, respectively. For millet, the stem heights ranged from 143.67±3.98 cm for PUC to 210.87±3.07 cm for POC11 and then to 201.07±2.54 cm for POC22. Lastly, sorghum stem heights were 78.47±3.24 cm for PUC, 108.13±3.45 cm for POC11, and 115.2±2.76 cm for POC22.

3.2 Effect of Neem on Photosynthetically Active Radiation and Linear Electron Flux of Associated Crops

The pairwise comparison test indicated that the photosynthetically active radiation was significantly lower in PUC compared to POC11 and POC22 across all crops (*P<0.05*). However, there was no significant difference between POC11 and POC22 (*P>0.05*). In terms of Linear electron flux, significant differences were observed among the treatments, especially between POC11 and PUC, POC22 and PUC, and between POC11 and POC22 (*P<0.05*). Notably, for cowpea, there was no significant difference detected between POC11 and POC22 (*P>0.05*) (Table 2).

3.3 Effect of Neem on Grain and Straw Yields of Associated Crops

For all three crops, POC22 plots showed significantly higher grain and straw yields when compared to the PUC plots (P*<0.05*) (Table 3). However, in the case of cowpea, there were no significant differences in grain yield (*P=0.32*) and straw yield (*P=0.26*) between the POC11 and POC22 plots or between POC11 and PUC. For millet, regardless of the yield, a significant difference was obtained between POC11 and POC22 (*P=0.02*), except for straw yield,

Table 1. Results of paired t-test for stem length and Leaf area index of associated crops

Parameters	Crops	Group1	Group2	N	Statistic	df	P.adj	Significance
Stem length	Cowpea	POC11	POC22	15	-3.21	27.90	**0.01**	**
		POC11	PUC	15	3.11	27.98	**0.01**	**
		POC22	PUC	15	6.36	27.78	**0.00**	***
	Millet	POC11	POC22	15	2.46	27.04	**0.02**	*
		POC11	PUC	15	13.38	26.31	**0.00**	***
		POC22	PUC	15	12.17	23.78	**0.00**	***
	Sorghum	POC11	POC22	15	-1.60	26.73	0.12	ns
		POC11	PUC	15	6.27	27.90	**0.00**	***
		POC22	PUC	15	8.62	27.31	**0.00**	***
Leaf area index	Cowpea	POC22	PUC	3	10.3	2.32	**0.01**	**
	Millet	POC22	PUC	3	4.13	2.25	**0.04**	*
	Sorgho	POC22	PUC	3	3.6	2.23	0.06	ns

Table 2. Photosynthetically active radiation and linear electron flow of associated crops

Parameters	Crops	Group1	Group2	N	Statistic	df	P.adj	Significance
Photosynthetically Active Radiation	Cowpea	POC11	POC22	24	-0.59	44.96	0.56	ns
		POC11	PUC	24	8.52	32.07	**0.00**	****
		POC22	PUC	24	10.44	34.90	**0.00**	****
	Millet	POC11	POC22	12	0.11	15.63	0.91	ns
		POC11	PUC	12	4.75	11.38	**0.00**	**
		POC22	PUC	12	9.56	12.70	**0.00**	****
	Sorghum	POC11	POC22	21	-1.53	39.99	0.13	ns
		POC11	PUC	21	5.72	25.93	**0.00**	****
		POC22	PUC	21	7.66	25.77	**0.00**	****
Linear Electron Flow	Cowpea	POC11	POC22	24	-0.89	44.37	0.38	ns
		POC11	PUC	24	6.77	37.17	**0.00**	**
		POC22	PUC	24	8.90	41.58	**0.00**	**
	Millet	POC11	POC22	12	1.87	21.91	0.07	ns
		POC11	PUC	12	13.52	18.37	**0.00**	**
		POC22	PUC	12	11.84	19.11	**0.00**	**
	Sorghum	POC11	POC22	21	-2.92	39.98	**0.01**	**
		POC11	PUC	21	6.16	34.23	**0.00**	**
		POC22	PUC	21	9.73	34.70	**0.00**	**

Table 3. Grain and straw yields of associated crops

Crops	Yield	Group1	Group2	N	Statistic	df	P.adj	Significance
Cowpea	Grain yield	POC11	POC22	3	-1.29	3.29	0.32	ns
		POC11	PUC	3	1.98	2.50	0.32	ns
		POC22	PUC	3	5.15	3.23	**0.03**	*
	Straw yield	POC11	POC22	3	-1.70	2.40	0.26	ns
		POC11	PUC	3	1.96	3.48	0.26	ns
		POC22	PUC	3	5.62	2.87	**0.04**	*
Millet	Grain yield	POC11	POC22	3	-7.50	2.38	**0.02**	*
		POC11	PUC	3	3.57	2.66	**0.04**	*
		POC22	PUC	3	8.60	3.71	**0.00**	**
	Straw yield	POC11	POC22	3	-5.47	2.74	**0.04**	*
		POC11	PUC	3	1.95	3.71	0.13	ns
		POC22	PUC	3	6.69	2.43	**0.04**	*
Sorghum	Grain yield	POC11	POC22	3	-0.47	3.34	0.67	ns
		POC11	PUC	3	8.15	3.76	**0.00**	**
		POC22	PUC	3	10.94	3.82	**0.00**	**
	Straw yield	POC11	POC22	3	-5.83	3.97	**0.01**	*
		POC11	PUC	3	2.36	3.20	0.09	ns
		POC22	PUC	3	6.44	3.04	**0.01**	*

where no significant difference was noted between POC11 and PUC(*P=0.13*). Regarding sorghum, significant differences were found for grain yield between POC11 and PUC, as well as POC22 and PUC (*P=0.00*). Similar significant differences were also noted between POC11 and POC22, and POC22 and PUC for straw yield (*P=0.01*). However, there were no statistically significant differences for straw yield between POC11 and PUC (*P=0.09*).

4. DISCUSSION

Reductions in stem length, grain yield, and straw yield were observed for all three crops in plots located under the crown of neem, compared with plots located at the edge of the crown and outside the crown. These results are consistent with the observations of Yelemou (1993), who noted that farmers had observed shorter crop stems under neem than outside its crown. Bazié (2007) and Zomboudré et al. (2005) also reported that millet and maize grew slowly in the shade of neem and shea trees, respectively. The reduction in stem length and lower crop yields under the crown of neem could be linked to its depressive influence on parameters such as Leaf Area Index, photosynthetically active radiation, and linear electron flux. Photosynthetically active radiation and linear electron flux were significantly lower in crops located under the neem crown. As these three crops are heliophilous, they require high levels of light to grow and develop properly. However, neem has dense, evergreen foliage that intercepts many of the light rays, thus depriving the crops beneath it of sufficient light for photosynthesis. This reduces their photosynthetic capacity, which can result in reduced synthesis of the organic substances needed to form and maintain leaves and produce biomass. For instance, sorghum cultivated beneath neem exhibited premature leaf senescence and a decrease in yield (Yelemou, 1993; Yougma, 1994; Bationo et al., 2004). It furthermore, by absorbing nutrients from the surrounding soil, reduces their availability to neighbouring crops, which could contribute to lower yields. This drop in yield can be attributed to a lack of fertilizer application and irregular rainfall, including droughts during the grain-filling phase, which negatively impacted yields.

5. CONCLUSION

The study indicates that the presence of neem trees adversely impacts the growth, physiology, and yields of three different crops. Neem trees grow rapidly and their evergreen foliage blocks sunlight, which lowers radiation levels beneath their canopy. This reduced light can hinder photosynthesis, leading to decreased yields. The findings emphasize that shading is a key factor affecting crop productivity in the vicinity of neem trees. To mitigate this issue, adopting pruning techniques may enhance crop yields in such areas. Additionally, it is recommended that shade-tolerant crops could be planted under neem trees, and farmers might consider pruning the neem trees prior to sowing to further improve yields.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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