**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**

**Abstract**

Neem is an exotic species that is used to implement reforestation. However, its competitive effects on surrounding crops have not been extensively studied 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 is based on the systematic allocation of treatments according to the gradient of the tree effect. There are three replicates of each crop, making a total of 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. The parameters, such as stem length, crop leaf area index, photosynthetically active radiation, linear electron flow, grain and straw yields, were measured. For the three crops, stem length, photosynthetically active radiation, linear electron flux, and crop leaf area index were significantly lower under the neem crown than those from outside the crown (*P<0.05*). Additionally, grain and straw yields were significantly lower under the neem crown than it was at the border and outside the crown (*P<0.05*) for all studied crops. These results illustrated that neem is detrimental to intercropping in agroecosystems.

**Keywords**: Competition, neem, shade, millet, cowpea, sorghum

**Introduction**

*Azadirachta indica* A. Juss, commonly known as neem, is an exotic species from India and has been introduced to our country (Bationo *et al*., 2004). Its ability to adapt to challenging pedoclimatic conditions makes it a key species for reforestation efforts to combat 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. Neem is also used in monospecific reforestation efforts to restore degraded soils (Lavaud, 2021). For instance, Chittapur and Gurumurthy (2018) reported that high soil microbial density was observed in areas near neem trees. Similarly, Honnayya (2024) and Oyinlola (2017) found that the availability of nutrients, especially nitrogen, phosphorus, and potassium, was greater near neem trees compared to plots from areas far away. A survey conducted by Bationo *et al*. (2004) in Burkina Faso revealed that 90% of interviewed farmers noted that neem leaves decompose quickly and enrich the soil beneath their trees. Additionally, microdosing of neem cake has been shown to enhance grain yields for maize (Traore *et al*., 2019). However, some authors reported negative effects of neem on neighboring crops. For example, Arbonnier (1988) noted that neem has an extensive root system that competes strongly with nearby crops. A similar observation was made in Nigeria, where neem is an invasive species that tends to replace local flora (Bello et al., 2023). Other studies have reported reduced growth and yield in certain cereals, such as pigeonpea cultivated 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. Therefore, it is essential to understand the nature and extent of the competitive influence of neem on surrounding crops. This understanding will help to develop better management methods for neem and improve agricultural productivity in areas where this species is increasingly spreading. Therefore, this study was to evaluate the influence of neem on the growth, physiology, and yield of three cereals noted as cowpea, sorghum, and millet in agroecosystems in Burkina Faso.

**Material and Methods**

**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 2022/2023 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).

**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. They are also well adapted to the climate, and each crop is more or less tolerant of drought and Striga sp. With regards to 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.

**Experimental Design**

The experimental design employed is based on a systematic allocation of treatments due to the tree effect gradient; it is called 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, treated as a replicate, was associated with three square plots of 100 m² (10 m x 10 m) each, resulting in a total number 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, labelled as PUC. The center of this second plot was positioned at 11 m from the neem trunk, labelled as POC11. The third plot was located at 22 m from the neem trunk labelled as POC22, serving as the control plot. Each plot is separated from its neighboring plots by 1 m (Figure 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. As a result, some plots were slightly offset from the ideal north-south orientation.

**Figure 1: Experimental Design**

**Experiment setup and Data Collection**

After a rainfall of at least 20 mm, the plots were ridge-ploughed using animal traction. Sowing 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 weeding operation 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 sampled plants, the stem length was measured using a tape measure. 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 chosen 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.

**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.

**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).

**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 neighboring 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.

**Results**

**Effect of neem** **on the** **stem length and Leaf area index of associated crops**

In all three crops, the results of pairwise comparison t-tests showed that crop stem lengths were significantly different between POC22 and PUC, POC11 and PUC, POC22 and POC11 (*P<0,05*) (Table 1), except between POC11 and POC22 for sorghum (*P=0.12*). Leaf area index (LAI) of crops was observed to be significantly different between POC22 and PUC for cowpea (*P=0.01*) and millet (*P=0.04*), except for sorghum, for which no significant difference was found (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, heights increased from 143.67±3.98 cm for PUC to 210.87±3.07 cm for POC11 and 201.07±2.54 cm for POC22. Regarding sorghum, stem heights were 78.47±3.24 cm; 108.13±3.45 cm and 115.2±2.76 cm for PUC, POC11, and POC22, respectively.

**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 |

***Effect of* neemon Photosynthetically Active Radiation and Linear Electron Flux of associated crops**

The pairwise comparison test showed 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*). The Linear electron flux was found to be highly different among the treatments, specifically between POC11 and PUC, POC22 and PUC, and POC11 and POC22 (*P<0.05*). However, for cowpea, no significant difference was detected between POC11 and POC22 (*P>0.05*) (Table 2).

**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** | **\*\*** |

**Effect of neem on Grain and Straw Yields of Associated Crops**

For all three crops, POC22 plots showed significantly higher grain and straw yields compared to PUC plots (P*<0.05*) (Table 3). However, for cowpea, grain yield (*P=0.32*) and straw yield (*P=0.26*) showed no significant difference between POC11 and POC22, POC11 and PUC. For millet, regardless of the yield, a significant difference was obtained between POC11 and POC22 (*P=0.02*), except between POC11 and PUC for straw yield (*P=0.13*). For sorghum, the difference was significant between grain yield in POC11 and PUC, POC22 and PUC (*P=0.00*), similarly between POC11 and POC22, also POC22 and PUC for straw yield (*P=0.01*). However, no statistically significant differences were observed between POC11 and PUC for straw yield (*P=0.09*).

**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** | **\*** |

**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 neighboring 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.

**Conclusion:**

The results of this study suggest that the crown of Neem has had a detrimental effect on the growth, physiology, and yield of the three crops. Neem is a fast-growing species whose evergreen leaves intercept sunlight, reducing radiation levels under its canopy. Indeed, the reduction in light under the canopy can limit photosynthesis, resulting in low yields. This study highlighted the depressive effect of neem on associated crops. It revealed that shade is the main factor limiting crop productivity near neem trees. To address this, pruning techniques could potentially improve crop yields under neem trees. As recommendations, shade-tolerant crops can be sown under neem. The farmers can also prune neem before sowing to improve crop yields.

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