



Original Article

Calibration of some Manageable Agronomic Requirements of Cowpea for Adaptation and into the Farming System of Wet Savannah Ecology of Nigeria.



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ABSTRACT

On-farm adaptive Research Methodology was adopted in the year 2023 at two locations to afford a simultaneous trial and transfer/adoption of the maize: cowpea inter-crop farming system. A factorial combination of three seed varieties {(i) Ife Brown-NGVU9-1-2 (ii) Ex-Borno (iii) IT90K-82-2 SAMPEA17}, three sowing dates {(i) 30/08/2023 (ii) 06/09/2023 (iii) 13/09/2023} and two geometric arrangements {(i) 1:2, (ii) 2:4} of cowpea: maize inter-crop. were combined in a factorial design and allocated in a completely randomized block design to the experimental plots. Ife brown was the first variety to attain 50% flowering within 37 days and 38 days, for Iloffa and Offa respectively. it also produced the tallest cowpea plants (35 and 30 cm) from the two locations. Variety IT90K-82-2-SAMPEA17 recorded the highest nodule count of 59.55 and 55.6. The largest leaf area was recorded from Ex-Borno 127 and 129 Cm², respectively, from location 1 & 2. Late sowing (on 13/09/2023) had a delayed flowering till 44.8 and 43.9 days after sowing. The tallest plants were still produced from sowing on 13/09/2023. Sowing seed on 30/08/2024 produced the largest leaf area (127.8 and 129 cm²). Cowpea sown 1:2 flowered earlier (46.59), while the tallest cowpea (33.7 and 29.15cm) were obtained from sowing in 2:4 spatial arrangements prospectively from location one and two. Sowing 1:2 recorded the higher leaf area of (3.03), while sowing in a 2:4 arrangement gave a higher LAI of (2.60). Ife Brown was observed to be best adapted to the wet Savannah ecology having recorded the most impressive values for the yield indicators when sown on 13 August in a 2:4 spatial arrangement.

1.0 Introduction

Cowpea [*Vigna unguiculata* (L Walp)] is a widely adapted leguminous species of tropical crops. (Ongom et al., 2024; Lydia 2020). The crop has been successfully cultivated in a diverse ecology globally, including in Nigeria (Hall 2004[Hall 2012). Cowpea thrives in a marginal soil because of the inherent ability to afford nitrogen, and the associated enhanced phosphorus utilization and water absorption as well. The enhanced soil nutrition in cowpea, which Becker et al., (2024) attributed to the success of biological N-fixation and the subsequent enhanced phosphorus socialization that was reported by Elhaissofi (2021);

Shome et al., (2022). Other related fact is the enhancement of water absorption facilitated by root-fungi association to form mycorrhiza as reported by Stacey et al., (2006); Kinkema et al., (2026).

The various dietetic challenges (including diabetic) and malnutrition due to natural disaster, insurgence and the general food scarcity consequent to climate change and global economy recession as documented by Petu-Ibikunle et al., (2010); Imran and Ibrahim (2022), created more awareness, acceptability and demand for cowpea as a staple food beyond its previous status as food for the wretched. The demand for cowpea is on the increase because of the



need to feed the teeming national population estimated further contributed to the decline in agricultural productivity, thus worsening to already existing food crisis to be 200 million (NBC 2020 and NPC 2022), while the menace of climate change (Petu-Ibikunle et al., 2010). The declining soil fertility is also an emerging environmental threat that was documented (Hutt and Frielinghaus 1994; Mosier et al., 2021) to have contributed adversely to soil productivity in general. Simbauni et al., (2024) reported that the production of cowpea is, however, constantly been impeded/confronted by a series of production constraints. The identified production constraints of cowpea spread from poor seed technology to pests and diseases to the inherent soil nutrient status. (Baoua et al. 2021). A cowpea farmer is expected to cope with other challenges like unpredictable weather conditions (Omomowo and Babalola 2021). It is also relevant to stress the point that crop production in general is laborious and capital-intensive even at subsistence/all scales and levels of operation (Vanlauwe et al., (2015). As a result of this, subsistence/small-scale farm size is still commonly associated with inherent poverty that prevails on the farmer's fields

As a result of the aforementioned, the farmers can hardly afford the high cost of hiring labour/ farming equipment, and inputs cost is generally high relative to the socioeconomic situation of the farmer.

Aside the aforementioned cowpea production constraints, it is obvious, that the wet Savannah is not considered as a major producer of cowpea. According to Akah et al., (2021); Kouakou et al., (2022) the North West and North Eastern regions of Nigeria are the highest producers, with a production record of 75% of Nigeria's total cowpea production. It is thus very important at this point to investigate strategies that would facilitate the introduction of cowpea into the farming system of wet Savannah ecological zones in Nigeria.

It is therefore necessary to carry out studies that would enhance the adoption of a maize: cowpea farming system and production technology that would synchronize the two (mixed-sole cropping and inter-cropping) farming systems into the wet Savannah zone of Nigeria. One issue of concern is how to persuade/convince a farmer practicing maize sole cropping on the advantage to adopting an inter-cropping farming system. There is thus a need to study the appropriate cowpea production technology that would put into compliance, a genotype with a combined multiple resistance/tolerance to pests and diseases, with appropriate adaptation to various prevailing environmental stresses. Kouakou et al., (2022) suggested that in the design of such trail On Farm Adaptive Research (OFAR) and Small Plot Adaptive Technology (SPAT) strategies should be involved in the design.

To achieve this major objective, the following sub-objectives are outlined as;

- i). to examine the best adapted variety for Cowpea maize inter-crop in the wet Savannah zone of Nigeria
- ii). to study the most appropriate sowing dates for cowpea in an inter-crop with maize

iii) to study the most appropriate crop spatial arrangement for cowpea in an inter-crop with maize.

iv). to involve the end users/farmers in the trial via On-Farm Adaptive Research methodology to achieve a simultaneous investigation, technology transfer and adoption of the recommended outcome.

2.0 METHODOLOGY

a). Description of the Experimental site.

The present trial was simultaneously conducted at Ilofffa and Offa in Kwara State of Nigeria during the year 2023 rainy season. Location 1: Ilofffa, in Oke Ero Local Government Area of Kwara State, Nigeria, 8° 06' 25.2" N 5° 08' 16.8" E while Offa, the second location was situated at 8° 09' N 4° 43' E. The rainfall characteristics is of the tropical humid savanna. The rainfall can value up to 101.45 millimeters pa year. and 148.38 rainy days with an uneven distribution. The night monthly mean temperature ranges from 22°C, and the day temperature during the rainy season could be up to 33°C. (NiMet, 2023).

b). Steps taken to achieve land preparation.

Stumping was done to remove of perennial roots and tree stumps existing in the soil. This was followed by Ploughing with the primary purpose of turning over the upper layer of the soil and bringing fresh nutrients to the surface. Harrowing was done on the fields to follow the 'rough-finish' left by ploughing operations. The purpose of this harrowing is generally to break up clods (lumps of soil) and to afford a well pulverized tilt that is appropriate for seedbed use.

c) Soil sampling and soil test

composite sampling involving collection of Sub-samples from randomly selected location in the field. The sub-samples were thoroughly blended to obtain a representative sample of which gives average values for the entire area. (FAO. 2020; Cordero (2023).

d). Seed Dressing/inoculation

To inoculate cowpea seeds with Rhizobium bacteria, the seeds were coated with a peat-based inoculant (from commercial bio-fertilizer). The inoculant - seed mixture was thoroughly agitated to ensuring each seed was sufficiently coated (Saskatchewan, 2023)

e). Agronomic Practices

i. Weeding: Two manual weeding were conducted at 2 weeks and 5 weeks after sowing.

ii. Fertilizer Application: single super phosphate (SUPA) was applied basal and incorporated into the soil during harrowing.

iii. Insect Pest control: Tobacco leaf extract [Sterols, diterpenoids, sesquiterpenes, alkanoids, (including nicotine, and phenolic compounds (like flavonoid, phenolic acid and coumarin)] extracted as described by Kheawfu (2021). The concentrated extract was applied at the rate of 4 litres in a 16 litre knap sack sprayer was applied at three stages of the cowpea development. (Pre - flower initiation, full flower, and 25% pod formation stage)

f) Experimental Design



On-farm Adaptive Research (OFAR) strategy as described by Versteeg and Huysman, (1998), Adeola *et al.* 2014, Eldon *et al.* (2020), was adopted for the present trial. A consultative meeting of end users (comprising of members of maize growers' association) was summoned. The objective of their involvement in OFAR trial was discussed and the roles each participating farmer would play were assigned. Eighteen (nine from each location) farmers were selected with the understanding that their farmlands would be used as the experimental plots.

The farm land/farmers were sectioned into in three categories.

- i. Sole crop maize (three farmland standing out as three replications)
- ii. Sole crop Cowpea (three farmland to representing three replications)
- iii. Cowpea- Maize Mixture (three farmland to representing three replications)

g). The Treatments factors allocation to the plots.

Each experimental unit were mapped out in a dimension 5m x 6m = 30m² plot size. The sole maize was spaced at 0.50 x 0.75, while the cowpea component was spaced at 0.50 x 0.50m for sole cowpea to obtain a plant population of 60 × 20 cm (83 333 plants).

- i). Experimental Crop 1: Maize (SAMMAZ 15 (IWDC2SYN-F2-W))
- ii). Experimental Crop 2: Cowpea varieties
 - ITK-82-2 SAMPEA17 (With grain yield potential of 694.4kg/h)
 - Ex-Borno (grain yield potential of 694.4kg/h maturity 65-75 days)
 - Ife Brown- NGVU 91-2 (With grain yield potential of 1200 kg/ha)

iii). Sowing Dates

- 06/08/2023 (Maize)
- 30/09/2023 (forty-two days after sowing maize)
- 13/09/2023 (forty-nine days after sowing maize)
- 17/09/2023 (fifty-six days after sowing maize)

h) Sowing Density/Spatial arrangement (Cowpea was spaced at 60 × 20 cm (83 333 plants ha⁻¹))

- 1:2 Maize: Cowpea Inter row arrangement.
- 2:4 Maize: Cowpea: Inter row arrangement

i). Harvesting

Cowpea was harvested as soon as the pods were fully matured and dry. Harvesting was achieved by handpicking the pods. After harvest, the pods were sun-dried on a platform for proper drying before threshing. Thereafter, thresh pods were winnowed to separate the seeds from the chaff/haulms.

j). Data Collection

i) Soil sampling and analysis was done according to TNAU. (2013)

ii). Days to 50% Flowering

Daily field observations were carried out on each plot to determine number of days per that was taken up to 50% of the experimental plants to initiate flowering.

iii) Plant Height

Measure the plant height in centimeters (cm) from the base of the stem (at the soil surface) to the top of the canopy, or the highest part of the plant (for many plants, this will be the tip of the apical bud). You may lift and support the stem if needed, but you cannot lift or extend leaves. With the stem supported, measure to the highest part of the plant. According to Mano and Igawa, (2017).

iv). Nodule Count

Fifteen sampled plants were destructively harvested, and the roots soaked in a container of water to wash of the adhered soil. With the aid of hand lens magnifier (×10) the nodules were counted and averaged.

v) Leaf Area.

The Length × breadth method described He *et al.* (2020) was adopted to determine the leaf area.

vi) Leaf Area Index

The methodology described by Apolo-Apolo *et al.*, (2020) was used to determine the leaf area index.

k). Data Analysis

Statistix 10. analytical software was used to analyse numerical data. Collated data were subjected the Analysis of Variance (ANOVA) for factorial design. Means of treatments that were relatively significantly different at $P \geq 0.05$ were compared by separating them from one another using Least Significant Difference (LSD) at ($P \geq 0.05$).

3.0 RESULTS AND DISCUSSION

a) The physio-chemical properties of the soils at the experimental sites

The mechanical analysis of the soil (location1) shows a particle size distribution of clay (12%), Sand (72%), and silt (16%). this classified the soil as sandy loam soil. The mechanical analysis (location 2) shows a proximate analysis of clay (15%), Sand (75%), and silt (10%). The soil is classified as sandy loam. The soil at Location 1 was 5.90 and 5.6 at location 2, translating to the two locations being slightly acidic soils. The macro nutrients at location (15, P₂O₅ was 20, K₂O 17 Mg/kg) and location 2, the macro nutrients (N=12, P=18, K=11 11ppm).

The soil is textually classified as sandy loam soil, similar to Vinhal-Freitas *et al.* (2017); Sérgio (2023), as being typical of most soils in the Guinea Savannah. The low macro nutrient status of the soil, according to Diri and Joseph (2020), Keita *et al.*, (2023) is inherent and common in the tropical soils. CEC (5.6 and 5.21, respectively, for locations 1&2 were rated to be marginally low. The inference of low CEC according to Hazelton and Murphy (2007) is apart from been associated with low pH value, the soils will also not be able to retain sufficient of essential nutrients (ammonium such as (NH⁴⁺), and cations (Ca²⁺, Mg²⁺, K⁺, and Na⁺)) like soils with higher CEC would do. The organic carbon is moderately high. (Davidson and Ivan 2006; Jackson *et al.*, 2017). Typically, the organic carbon



content of tropical agricultural soils is between 0.7% and 4%.

b). Days to 50% flowering

i. Effect Inherent cowpea trait exhibited as days to 50% flowering

All 3 varieties are significantly different ($P \geq 0.05$) from one another in the number of days taken to attain 50% flowering (Table 2). The results from the two locations showed that the most significant ($P \geq 0.05$) delay of 37 and 38 days, were recorded from Ife Brown. Ex-Borno, ranked second with respective record of 45.5 and 47.17 from locations 1 and 2. This result agrees with Craufurd (1997), Nuhu and Muktha (2013), who reported that a considerable variation exists among genotypes in their sensitivity and responsiveness of flowering to photoperiodicity. Early or delayed flowering may be due to the photo sensitivity of the genotype as reported by Shavrukov (2017). The inheritance of time of flowering according to Ishiyaku et al., (2005); Owusu (2018); Ukpene and Isibor (2022) also agreed with the present findings. The relationship between flowering and genotype was further explained by Ndenkyanti (2002), Zhang et al., (2023) as a function of dominant gene being the most important physiological factor that conditions the time of flowering. Time taken to attain flower initiation is a factor in the present study, being determined by morphological and anatomical phenomena. Ife Brown, with a record of the earliest flowering, may be an indication of adaptation to a short period of rainfall, which is considered an advantage where a considerable dryness is needed during flower initiation to avoid flower damage.

ii) Effect of Sowing Date on Days to 50% flowering

The days the cowpea was introduced (i.e, sown) into the (Maize/Cowpea) mixture significantly ($P \geq 0.05$) reduced the day taken to attain 50% flowering in Cowpea (Table 2). The 3 sowing dates significantly ($P \geq 0.05$) influenced days taken cowpea to attain 50% flowering. The result from the two locations consistently follow a similar trend. Sowing on 30/08/2023 resulted in a reduction of 42.83 days, while sowing on 13/09/2023 delayed 50% flowering till 48.89 days after sowing. Introducing cowpea into the inter-crop on 06/09/2023 likewise reduced the number of day to attain 50% flowering to 45.67. The result agrees with Tekle and Alemu (2016) with the expatiation that early flowering, amongst other dependent variables, is considered to be the best adaptation to environmental stress. The work of Kátia et al., (2023); Galleguillos (2023) further explained that under prevailing low moisture situation early flowering will be induced. Barrett and Brown (2021) supported that rainfall also influences the pheno phases of crops. The Physiological explanation is that moisture stress stimulates changes in gas exchange and energy metabolism. Ishiyaku et al., (2005), Singh et al. (2017); Zhao et al., (2017); Adole et al., (2019) supported that photo-period is also a determinate environmental factor in plant phenology. The various scholars opined that the time taken to attain flower initiation and flower maturity is important adaptive feature controlled by photo-period. Temperature is another factor described by Do et al., (1996); Chmielewski and Rötzer

(2001); Dai et al. (2013), Hudson et al., (2009); Keatley and Hudson (2000); to be a factor that is highly relevant in crop phenology. It should thus be noted that in calibrating for sowing date in a new environment, the paramount factors being investigated are the environmental factors. A short life span, otherwise called early-maturity, according to Álvarez et al., (2018), is actually an acquired adaptation to escape adverse conditions like drought/moisture stress, which is typical and prevalent under an-arid condition.

iii. Effect of Spatial Arrangement on Days to 50% flowering
Spatial arrangement (Table 2) significantly (Table 2) reduced days to 50% flowering on location 1 to 45 days in response to 1:2 spatial arrangement. Sowing in a 2:4 spatial arrangement had a delay of 48.56 days to attain 50% flowering. This result agrees with Agele et al., (2007), with the explanation that crops in wider rows intercepted more radiation than their counterparts in narrow rows due to the shading effect from closer neighbouring plants. The non significant (Table 2) difference in days taken to attain 50% flowering between the two spatial arrangements at location 2 also agreed with Bugilla et al., (2024). This result is also consistent with Nurgi et al., (2013) record of days to 50% tasseling and days to 50% silking were not significantly affected by the spatial arrangement of component crops. Wang (2024) explained that in an inter-cropping system, spacing, spatial arrangement, and plant population are the major variables being studied. They are ordinarily expected to impact on light quality by varying the quality and quantity of incoming photosynthetic active radiation (PAR) between and within rows of crops.

c). Plant Height (cm)

i). Effect of Inherent Cowpea Trait Expressed on Plant Height

Cowpea height (Table 2) was significantly different ($P \geq 0.05$) amongst cowpea cultivars at the two location. ITK-82-2 SAMPEA17, with plant heights of 35.00 and 30.00 cm, respectively, from location 1 and 2, was the tallest variety from both location. At location two, Ife Brown and Ex-Borno were not different in height, while ITK-82-2 SAMPEA17 was the shortest plant from the two location. The result is consistent with Jogdhande et al., (2017). The result was further supported by Lingdi et al., (2019) in the report that variation in height of cowpea and Jonah et al., (2024); El-Naim et al., (2012) explained that cowpea height is one of the vital genetic factors of interest when screening cowpea for environmental adaptation. Height could be an advantage in cases of water logging and shading because stretching is an adaptation for more efficient capture of PAR. This was justified by Srinivas et al., (2017), Molosiwa et al., (2020); Gerrano et al., (2022) with records that variety and genotype were found to vary in growth and yield, and quality parameters.

The role of genes in plant height was explained by Fery & Singh (1997); Alidu (2019); Maduwanthi and Karunaratna (2020) that the average Hb (ie, the proportion of phenotypic variance attributable to genetic) estimates for plant height was 71%. Odeseye et al. (2022) supported that plant height is a genetic issue. The contrasting results in genotype



between the location in the present experiments is not uncommon. This was explained by Baye *et al.*, (2011); Saltz *et al.*, (2011); Pham *et al.*, (2014) with an explanation that when the same genotype is subjected to different environments, a wide range of phenotypes can result. These phenotypic variations are attributable to the effect of the environment on the expression and function of genes (Bb) influencing the trait.

ii. Effect of Sowing Date on Plant Height

Sowing dates significantly ($P \geq 0.05$) increased plant height from both location (Table 2). At location 1, the means of the plant heights recorded for the 3 sowing dates were different from one another, while at location 2, only two means were different from one another. The tallest plants were recorded at location 1 (35.00cm) and location 2 (30.00cm) from sowing on 13/09/2023. Cowpea sown on 06/09/2023 were rated second in height (30.94cm) while at location 2, the plant heights were not significantly ($P \geq 0.05$) different for sowing either on 06/09/2023 or 30/08/2023. The result is consistent with Akande *et al.*, (2012), with the report that planting date affects plant height. This is inconsistent with Nwofia (2018), with a published report that plant height was not affected by sowing date. The level of incoming light and temperature (which varies as modified by cloudiness) may cause an array of morphological, anatomical, physiological, and biochemical changes. Physiological determinants of growth include light interception, light use efficiency, dry matter accumulation, duration of growth, and dry matter partitioning as contained in the reports of Munir *et al.*, (2004), Rawal *et al.*, (2015).

iii. Effect of Spatial arrangement on plant height.

Plant heights were significantly different from one another ($P \geq 0.05$) between the spatial arrangements at the two location. The tallest plants, 33.37cm and 29.15cm, were respectively recorded from location 1 and 2 when crops were sown in a 1:2 mixture. Shorter plants 30.30cm and 20.04cm were respectively recorded from a crop mixture of 2:4. This result is consistent with Gaikwad *et al.* (2022). The present study can leverage on the consistency with the work of Paradiso and Proietti (2021). It was observed that light intensity has a direct proportional relationship with photosynthesis; thus, at a reduced light intensity, root and shoot growth (vegetative growth) will be inhibited with a reduction in translocation of water, nutrients, and assimilates. Long and Bernacchi (2023); Barros *et al.*, (2023) further explained that aside the interception of solar income, shade casting also modifies the crops immediate environment such as such as air and ground temperature, humidity, carbon dioxide (CO₂) concentrations, which are important for plant growth and movement of plant hormone to target-site (i.e, assimilate partitioning), including growing tissues, especially apical and lateral meristems. Willige *et al.*, (2013) added that Auxin, the phytohormone responsible for plant elongation, is formed at the plant's shoot tip. The physiological explanation is that under the shade or low light intensity, a shaded part of the stem contains more auxin and grows longer (stretching towards the light source/phototropism), which causes the stem to grow towards the light. Thus, cowpea under a 1:2 arrangement, being under more shade effect, grows taller

c) Nodule count

i Effect: Inherent cowpea trait exhibited nodulation

There was a significant ($P \geq 0.05$) difference in cowpea's nodule count amongst the three varieties (Table 2). The result invariably followed the same trend in the two location. IT90K-82-2 SAMPEA17 nodulated highest with 59.55 and 55.61 nodules, respectively from locations 1 and 2. Ex Borno ranked second, while Ife Brown ranked lowest in nodule count. This is consistent with Ado (2017), Abaidoo *et al.* 2017, Aredo and Nebiyu (2021). The result can further be explained, citing the work of Jayawardhane (2022), that cowpea genotypes were bred and modified to respond or adapt to different kinds and levels of environmental stress/conditions. These responses/adaptations are possibly the various displayed morphological expressions/reactions, including nodule characteristics (such as number, weight, and size). This was further supported by Mohammed *et al.* (2022) that a significant genotypic variation was observed amongst traits an organism can acquire (phenes), and high fitness was observed for root architectural phenotypes (including primary/basal root length and number, root hair, taproot branching and distribution). The root architectural phenotype. distributions are highly relevant in determining the success and extent of nodulation. Thus turned out to be a major suspected reason for genotypic differences in nodule count. Further explanation by Stacey *et al.* (2006) was that heavy nodulation may sometimes result to less effective nodules due to factors like excessive nitrogen, which can inhibit nitrogenase (an enzyme responsible for converting atmospheric nitrogen into usable forms) activity. This feedback mechanism reduces the need for the plant to rely on symbiotic nitrogen fixation, leading to less effective nodules, environmental stresses, and the plant's resource allocation strategies. As the plant ages, nodules can die off or become less effective, even when several nodules are still large. This may be the reason why the best nodule-yielding variety (IT90K-82-2 SAMPEA17) did not give the overall best performance in superiority to other varieties.

ii. Effect of Sowing Date on Cowpea Nodulation

Cowpea nodulation (Table 2) was significantly ($P \geq 0.05$) increased by sowing dates. The result was consistent in trend from the two locations, with the highest nodule count of 58.28 and 54.50, respectively, recorded from location 1 and 2 from sowing on 13/09/2023. Sowing cowpea on 06/09/2023 ranked second in nodule count, and the lowest nodule counts (52.00 from location 1 and 48.00 from location 2) were observed on cowpea sown on 30/08/2023. The result of the present study is consistent with Bayei *et al.*, (2020). It was reported that the time of introducing cowpea in a maize-cowpea inter-crop had a significant effect on the nodules formation of cowpea sown four weeks after sowing maize. Reports by Gibson (1971), Bordeleau and Prevost (1994) explained that the sub-optimal temperature and moisture (variations) are possible prime causes of nodulation status. The climatic elements (moisture and temperature) are salient factors of serious consideration in any sowing date calibrating experiment. This is because they are capable of affecting all phases of



the root-bacteria symbiosis association, development, and survival in soil. Temperature and moisture also impart an undesirable alteration in rhizobia, including plasmid deletions, genomic rearrangements, and diminished diversity. In the present study, late sowing probably fell within the period of optimum temperature and moisture regime that favoured nodulation. The present result can then be translated to mean that sowing on 13/09/2023 afforded the most optimum climatic environment that was favourable to nodulation.

iii. Effect of Spatial arrangement on cowpea nodulation.

Cowpea nodulation (Table 2) was significantly ($P \geq 0.05$) increased by the spatial arrangement of the crops in the intercrop mixture. The results consistently follow a similar trend at the two location. The crop mixture in a 2:4 spatial arrangement nodulated higher with 56.07 and 52.07 nodules, respectively, from location 1 and 2. Sowing in a 1:2 spatial arrangement gave lower values of nodule number, 54.59 and 50.77, respectively, from location 1 and 2. This observation is consistent with Begam (2023), Kombat et al. (2024), Chmielewski et al. (2024), nodulation was increased by crop geometry.

It was documented that spatial arrangement is a modifier of the crop's environment. The result was ascribed to possible improved soil fertility via better soil temperature modification, weeds and erosion control, and soil moisture conservation. In a related study, Thierfelder *et al.*, (2012) reported that Inter-cropping maize with legumes ensures flexibility in planting and soil conservation, while Verret *et al.*, (2017) also confirmed that maize-legume mixed cropping enhances soil carbon sequestration, reinforced resistance to soil erosion, put weeds under check and enhanced resource use efficiency efficient use of resources.

d). Leaf Area

i). Effect: Inherent cowpea trait exhibited as leaf area.

Leaf area (Table 2) was significantly different ($P \geq 0.05$) amongst the three cowpea varieties. The result similarly followed a consistent trend between the two locations. The largest leaf area, 120.16 and 121.40 cm², was recorded from location 1 and 2. Ex-Borno ranked second with 122.0 and 123.95 cm², respectively, from locations 1 and 2, while the smallest leaf areas were recorded from IT90K-82-2 SAMPEA17 at the two locations. This result is supported by Nwofia *et al.*, (2015) that the leaf area of was significantly increased by cowpea cultivars. Leaf area, according to Bastos *et al.*, (2011), may be an adaptation trait developed while breeding for tolerance to moisture and drought stress. The importance of genotypic leaf area, according to Rodrigues et al. (2017) is linked to water use efficiency.

ii) Effect of Sowing Date on Leaf Area.

Leaf area (Table 2) was significantly ($P \geq 0.05$) increased by sowing dates. The results between the two location are consistently similar in trend Sowing on 30/08/2023 gave the widest leaf areas of 127.84 and 129.83, respectively, from location 1 and 2. The leaf area recorded from sowing on 06/09/2023 ranked second with 126.55 and 127.92 cm², respectively, from location 1 and 2. The results translate

further to sowing on 30/08/2023 yielded the smallest leaf areas at the two location, which is similar to Ndagana *et al.*, (2023), with the observation that leaf area responded to sowing date. The result also agreed with Danie *et al.*, (2011) that a strong correlation exists between the leaf area (leaf shape and size) and the climate. Warmer temperatures for the leaf were observed to have enhanced both photosynthesis and transpiration. This explains why crops in arid environments tend to develop smaller leaves as an adaptation to minimize evapo transpiration. on the other hand, in humid climates, bigger foliage is common due to the incidental water cost being less critical. This is also supported by Rosbakh *et al.*, (2015) with a proposal that leaf area possibly reflects plant responses to climatic changes, due to its strong link with temperature. It should be noted that in the present trial, temperature increases as the weather is getting drier toward the end of the season.

iii) Effect of Spatial arrangement on leaf area.

Cowpeas' leaf area (Table 2) was significantly ($P \geq 0.05$) increased by the spatial arrangement used in the mixed culture. This result was consistently similar between location 1 and 2. The implication is that the leaf area for the spatial arrangements was different from one another. The highest leaf area, valued at 123.53 and 125.38 cm², respectively, for location 1 and location 2, was recorded from sowing in a 1:2 arrangement. The result is consistent with Ewansihaa *et al.*, (2014). The larger leaf area recorded from sowing 1:2 can be explained by taking into consideration three major climatic elements, according to Shirke and Pathre (2003) that are involved. They are Light interception, Temperature, and CO₂ concentration. Reports by Yao et al. (2017), Wu et al., (2017), Terashima *et al.*, (2016) can further be relied on to explain the present result that leaf area increases with low light intensity because leaves growing under shade expand better than leaves exposed to full light intensity. The reason is that surface area is an adaptation to provide a greater surface and a higher concentration of chlorophyll to maximize light capturing. In the present study, the cowpea component of 1:2 cowpea: maize inter-crop possible experience more shade effect from the maize being a taller component of the mixture. The shade effect was relatively less intense in the 2:4 spatial arrangement because the rows of the maize component were spaced wider away from the cowpea component of the mixture.

e.) Leaf Area Index (LAI)

i). Effect of Inherent cowpea trait exhibited as leaf area.

There were no significant ($P \geq 0.05$) pairwise differences in LAI among the varietal means from the two location of the experiment (Table 2). This result agrees with Ayalew *et al.*, (2022). The explanation from Putul (2021) was that leaf the area can increase or decrease based on several leaves and leaf expansion in a plant, which is a function of when the readings/measurements were taken. According to Karikari and Arkorful (1985), Leaf Area Index has a directly proportional relationship with to age of plants. This may also be the reason for the contrast in the report of Gerrano *et al.*, (2019). According to Yin *et al.*, (2023), Leaf Area Index varies with species, cultivars, and growing conditions. The conflicting results can thus be attributed to the interaction



of the environment and the phenotype (characteristics/traits of a cultivar consequent and after the interaction of its genotype with the environment) on the genotype (which is a score of the type of variant present at a given location (i.e., a locus) in the genome). Hashimoto (2023); Patil *et al.*, (2018) supported with the explanation that agronomic practices alter growing conditions and thus regulate plant growth and development, and may hence alter LAI for the same cultivars.

ii) Effect of Sowing Date on as Leaf Area (LAI)

There were no significant ($P \geq 0.05$) pairwise differences influenced by sowing dates among the means of the leaf area from the two location (Table 2). This result is inconsistent with Ntombela (2012), who showed that water regimes as a consequence of sowing date had a significant ($P \geq 0.05$) effect on LAI. The present study has a limitation of not investigate the LAI over a range of time. Time of sowing cowpea in the intercrop is important, according to Iwuagwu *et al.*, (2020), Sattar *et al.*, (2010), environmental factors such as temperature within the canopy may decrease LA. Rahmati *et al.*, (2024) explained further that temperature, soil moisture content, and general management, e.g., soil aggregate size, sowing date, as additional factors that may decrease LA.

iii). Effect of Spatial arrangement on as leaf Area

All 2 means of LA in response to spatial arrangements are significantly ($p \geq 0.05$) different from one another between the two locations. A crop geometry of 4:2 gave the higher LA of 3.03 and 2.60, respectively, from locations 1 and 2. This result agreed with the results and explanation by Winck *et al.*, (2020) that crops at high densities will accordingly have an increase in leaf area index due to improvement in the efficiency of light capturing /interception. In the present study, plant geometry possibly affects the behavior of the Eco-physiological variables like plastochron (The time interval between the initiation of two successive leaves at the shoot apical meristem (SAM), leaf life span. The work of Chaulagain *et al.*, (2023), Yin *et al.*, (2023) explained further that LA varies with growing conditions and crop growth stages. The LAI describes the density of the vegetative layer that covers the soil surface. This has the consequence of affecting the external surface temperature and heat flux (the rate at which heat energy is transferred across the surface per unit area) reduction. Ren (2021) added that environmental factors such as temperature, photosynthetic active radiation (PAR), and moisture significant impacted on the growth and development of plants. This is because of the modifications of the immediate crop environment. Leaf sizes positively

correlated with growing-season temperature and precipitation, suggesting that sorting and screening environmental resources play an important role in affecting leaf size than phylogeny. The underlying factor here is according to Uzun (2007), is that light intensity and photo-period greatly impact crop phenological development. This is in combination with temperature, since shading may result in temperature modification to give the highest yield per plant.

4.0 CONCLUSION

Soil physico-chemical analysis was carried out on the soils of the experimental location. The result shows that the soil was sandy loam, moderately acidic, with low CEC. The NPK status was low. There were slight variations in the soil properties from the two locations, which were eventually suggested to be a possible source of the slight inconsistency recorded in the results from the two locations. The Ife brown cultivar had a delayed flowering, making it suitable for flower maturity at a date that would coincide with less rainfall. The tallest plant was also recorded by Ife brown. This is also an advantage in an intercrop where cowpea occupies the ground storey. Ex Borno recorded a higher leaf area compared with Ife Brown. Ife brown, being taller, may use height to compensate for the leaf area under the shade. The best morphological performances, such as delayed flowering, plant height, nodule count, and leaf area, were recorded from sowing on 13/09/2023. Higher plant height, Nodulation, and leaf area index were recorded from sowing in a 2:4 crop arrangement. LAI recorded values higher than leaf area index are possible due to the plant having a large leaf area clustered on a smaller ground area. The transnational is that a higher LAI indicates more leaf areas to capture light, leading to better growth and a higher yield potential. The field performance of cowpea was significantly affected by the of variety which a function of the genotype, sowing date which comprises of (environmental variables), and crop arrangement (inter-cropping) that modifies the light quality, quality and duration. These factors (variety, sowing date and crop arrangement) influenced morphological parameters like, growth and development and time to maturity. To be precise, Ife brown varieties thrived well when inter-cropped with maize at a specific planting date (13/09/2023).

Recommendation

Based on the findings of the present study, the consultative group of farmers should adopt the cultivation of Ife Brown to be sown on 13/09/2023 in a 2:4 spatial arrangement

Table 1. Soil Physio-chemical Analysis from locations 1 and 2

Soil properties	Desirable range*	Location	
		Ilofffa	Offa
Clay (%)		12	15
Sand(%)		72	75
Silt (%)		16	10
N (mg/kg)	20-50 (PPM)	15	12
P (mg/kg)	4-21 mg/kg (PPM)	20	18
K (mg/kg)	14-20	17	11
Organic C (%)	Less than 1.9- 2 is normal	2.56	2.1
CEC meq/100kg	80-20	17	11
pH CaCl ₂	5-10	5.60	5.21
pH (H ₂ O)	Not less than 5.5	5.9	5.6

1 mg/kg is equivalent to 1 ppm. and (ppm) or milligrams per liter (mg/l) same as cmol(+)/kg
 *(Hazelton and Murphy.(2007) In Mosaic crop nutrition, (2024)

Table 2: Effect of Variety x Sowing Dates x Crop Density of Cowpea in a Mixed Culture with Maize in the wet Savannah Ecological Zone of Nigeria

	Days to 50% flowering		Plant Height (cm)		Nodule Count		Leaf Area(cm ²)		Leaf Area Index	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
Treatment										
A.) Cowpea										
Variety										
i). IT90K-82-2 SAMPEA17	54.89a	56.67a	27.22c	23.22b	59.55a	55.61a	120.16c	121.40c	3.216a	2.756a
ii). Ex Borno	45.50b	47.17b	33.28b	29.56a	54.39b	50.33b	127.18a	129.34a	3.188a	2.765a
iii). Ife Brown	37.00c	38.00c	35.00a	30.00a	52.38c	48.31c	122.00b	123.95b	3.175a	2.818a
SE±	0.045	0.45	0.34	0.52	11.57	11.58	0.14	0.45	0.1527	0.1514
LSD P≥0.05	0.092	0.92	0.67	1.05	3.36	4.18	0.39	0.24	0.3742	0.3712
B.) Sowing Dates										
i). 30/08/2023	48.89a	49.94c	32.00c	27.44ab	52.00c	48.00c	127.84a	129.83a	3.206a	2.739a
ii). 06/09/2023	45.67b	48.06b	30.94b	27.06b	55.72b	51.78b	126.55b	127.92b	3.206a	2.794a
iii). 13/09/2023	42.83 c	43.94c	35.00a	28.28a	58.28a	54.50a	114.94c	116.94c	3.167a	2.806a
SE±	0.045	0.45	0.34	0.52	8.89	8.22	0.15	0.45	0.151	0.151
LSD P≥0.05	0.092	0.92	0.69	1.05	3.74	2.97	0.33	0.98	0.371	0.371
C.) Spatial Arrangement										
i). 1:2	46.59a	48.56a	30.30b	20.04b	54.59b	52.07a	123.53a	125.38a	3.36b	2.96b
ii). 2:4	45.00b	46.00b	33.37a	29.15a	56.07a	50.77b	112.69b	124.41b	3.03a	2.60a
SE±	0.037	0.037	0.28	0.42	2.12	1.44	0.18	0.37	0.125	0.125
LSD P≥0.05	0.075	0.75	0.57	0.88	0.90	0.52	0.40	0.98	0.253	0.251

SE± = Standard Error LSD P≥0.05= Least Significant Difference at 95% Confidence Interval

Mean having same alphabets are not significantly diff from one another at P≥0.

L1 = (Ilofffa), L2= (Offa)

Author's contributions:

- a). Petu - Ibikunle A.M (Ph.D) is the Agronomist/Crop physiologist and the team lead that designed the experiment, and supervised the field work. He also carried out the statistical analysis and translated the results.
- b). Aliyu, M (Ph.D) is the soil scientist/Chemist in the group, he was responsible for the soil test and translated the soils chemical properties.
- c.) Alawode Y. (M.Sc) is the plant breeder in the group, she searched for and recommended \ the cowpea and maize varieties used. She also discussed the genetic implications of the results.
- e). Okwukenye. Goddey F. (Ph.D) is an Agricultural Exhibitionist in the team. He included the On-Farm Adaptive Research Methodology in the experiment. He organized the consultative group meetings of the participating farmers. An carried out the field supervision of the experiment on the farmers field.
- f). Tenebe. V.A (Professor) is an Agronomist and farming system expert. He was responsible for overall experimental design and data collation and storage.

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