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Diversified cowpea cropping design in the Sudan Savannah of Ghana*

Diseño diversificado del cultivo de caupí en la sabana sudanesa de Ghana

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Abstract

Introduction. Climate change and low-intensity cropping technologies limit cowpea [*Vigna unguiculata* (L.) Walp.] yield in sub-Saharan Africa. **Objective.** To implement and optimize high-intensity climate-smart cropping systems for cowpea. **Materials and methods.** Cowpea was planted using four seeds per hill, spaced at 75 × 20 cm in a randomized complete block design with four replicates, and later thinned to the required stand at the Savanna Agricultural Research Institute, Manga, Ghana, in 2021 and 2022. Four planting designs were used: a single row with two plants per hill at the center of the ridge (66 667 plants/ha); a single row with one plant per hill at the center of the ridge (33 333 plants/ha); a double row with two plants per hill on both sides of the ridge (133 333 plants/ha); and a double row with one plant per hill on both sides of the ridge (66 667 plants/ha). Days to 50 % and 90 % flowering, pod load and pod length, number of seeds per pod and 100-seed weight, and grain and biomass yields were recorded. **Results.** Planting designs and plant densities had no effect on the number of days to flowering. A single row with two plants per hill or a double row with one plant per hill increased pod load. A single row with two plants per hill or a single row with one plant per hill improved the number of seeds per pod. Planting a single row of two plants per hill or a double row of two plants per hill optimized grain and biomass yields. **Conclusions.** Different planting designs and plant densities can enhance pod load, improve the number of seeds per pod, and optimize cowpea grain and biomass yields.

Keywords: legume, cropping technology, sustainable cropping, spacing, smallholder farmers.

Resumen

Introducción. El cambio climático y las tecnologías de cultivo de baja intensidad limitan el rendimiento del caupí (*Vigna unguiculata* [L.] Walp.) en África subsahariana. **Objetivo.** Implementar y optimizar sistemas de cultivo de alta intensidad climáticamente inteligentes para el caupí. **Materiales y métodos.** El caupí se sembró con cuatro semillas por golpe, espaciadas a 75 × 20 cm, en un diseño de bloques completos al azar con cuatro repeticiones, y posteriormente se aclareó hasta alcanzar la densidad requerida en el Savanna Agricultural Research Institute, Manga, Ghana, en 2021 y 2022. Se utilizaron cuatro diseños de siembra: una hilera simple de dos plantas por golpe en el centro del camellón (66 667 plantas/ha), una hilera simple de una planta por golpe en el centro del camellón (33 333 plantas/ha), una doble hilera de dos plantas por golpe en ambos lados del camellón (133 333 plantas/ha), y una doble hilera de una planta por golpe en ambos lados del camellón (66 667 plantas/ha). Se registraron los días hasta el 50 % y 90 % de floración, carga de vainas, longitud de vainas, número de semillas, peso de 100 semillas y rendimiento de grano y biomasa. **Resultados.** Los diseños de siembra y las densidades de plantas no afectaron los días a la floración. Una hilera simple con dos plantas por golpe o una hilera doble con una planta por golpe aumentó la carga de vainas. Una hilera simple con dos plantas o una con una planta por golpe mejoró las semillas por vaina. La hilera simple con dos plantas y la doble con dos plantas optimizaron el rendimiento de grano y biomasa. **Conclusiones.** Los diferentes diseños de siembra y densidades de plantas pueden incrementar la carga de vainas, mejorar el número de semillas por vaina y optimizar los rendimientos de grano y biomasa del caupí.

Palabras clave: leguminosas, tecnología de cultivo, cultivo sostenible, espaciamiento, pequeños agricultores.

Introduction

Globally, cowpea [*Vigna unguiculata* (L.) Walp.] is an important food legume, with Africa being a major production and consumption region. The continent produces and consumes approximately 5.2 to 6.1 million tons annually, highlighting its critical role in food and nutrition security. Cowpea is the second most important legume after groundnuts in Ghana in terms of area cultivated, quantity produced, and annual consumption (Egbadzor et al., 2013). Despite its importance, smallholder farmers face several challenges when cultivating it in the Sudan and Guinea Savanna ecosystems of Ghana. With a moderately dry environment and abundant sunshine for drying, the Savanna ecosystems account for the bulk of Ghana's production.

Low yields caused by pest and disease infestations, declining soil fertility, climate change, poor cropping technologies, and the high cost of inputs required to improve production are some of the key challenges. The crop is mainly grown by smallholder farmers with limited resources, primarily women and children, with an average farm size of 0.5 ha (Baributsa et al., 2019; Beye et al., 2022). Recently, medium to large-scale farmers have turned their attention to the crop to increase production owing to rising cowpea market prices. The grains and leaves of cowpeas contain valuable amounts of protein and serve as an important source of nutrition for poor and vulnerable households.

In addition to being consumed by humans, the dry stalks are also used as animal feed (Gerrano et al., 2019; Mekonnen et al., 2022). Besides the abiotic and biotic stresses affecting cowpea production, the existing cropping practices can limit cowpea yield. Due to inadequate cropping technologies, the low yield potential of current cultivars remains a barrier to increasing grain and biomass yields. Cowpea varieties with different plant morphologies require different optimal plant densities to reach their full yield potential (Falconnier et al., 2016; Nwofia et al., 2014). Conventional row spacing for cowpea cultivation does not consider the specific requirements of individual plants and varieties (Cisse, 2001).

Agronomic practices such as optimal plant population, integrated pest management, and appropriate cropping systems can increase cowpea productivity (Kamara, Omoigui et al., 2018). Optimized plant density can significantly increase grain and biomass yields per unit area (Kamara, Tofa et al., 2018), but the number of pods per plant, 100-seed weight, seed yield per plant, and harvest index at optimized densities can be negatively affected (El Naim & Jabereldar, 2010). Farmers in Ghana's Savanna regions must modify their farming practices to cope with a changing climate. Climate-smart cropping systems should be intensified to mitigate the effects and adapt to climate variability. The objective of this study was to implement and optimize high-intensity climate-smart cropping systems for cowpea.

Materials and methods

The study was conducted from July to October during the 2021 and 2022 cropping seasons at the research field of the Council for Scientific and Industrial Research – Savanna Agricultural Research Institute in Manga (11°01'N, 0°16'W), located in the Sudan Savanna ecological zone of Ghana. Rainfall typically begins in mid-May and ends in early October, with the remaining months being dry and hazy. Annual precipitation is about 1 200 mm, and the average temperature is around 27.3 °C, with the hottest months occurring from March through May. The soil is well-drained, has low organic matter content, and consists of brownish fine sand (Senayah et al., 2005).

Planting was carried out on July 2–3 in 2021 and 2022, using four seeds per hill in a randomized complete block design, and plants were later thinned to the desired plant population. There were four planting designs: AA – a single row of two plants per hill at the center of the ridge, 66 667 plants/ha (medium density); AB – a single row of one plant per hill at the center of the ridge, 33 333 plants/ha (low density); AC – a double row of two plants per hill at the sides of the ridge, 133 333 plants/ha (high density/optimized); and AD – a double row of one plant per hill at the sides of the ridge, 66 667 plants/ha (medium density) (Figure 1).

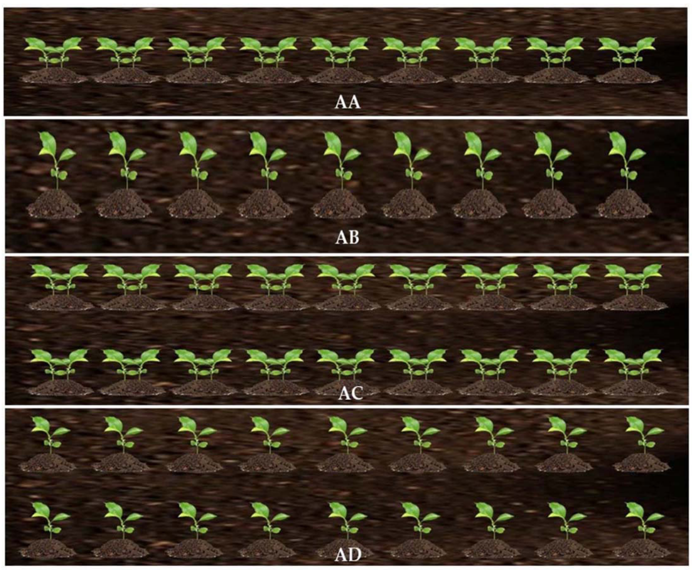

Figure 1. Schematic representation of the four cowpea planting designs evaluated during 2021 and 2022 at Manga, Ghana.

AA: Single row with two plants per hill at the center of the ridge, 66 667 plants/ha. **AB:** Single row with one plant per hill at the center of the ridge, 33 333 plants/ha. **AC:** Double row with two plants per hill on both sides of the ridge, 133 333 plants/ha. **AD:** Double row with one plant per hill on both sides of the ridge, 66 667 plants/ha.

Figura 1. Representación esquemática de los cuatro diseños de siembra de caupí evaluados durante 2021 y 2022 en Manga, Ghana.

AA: Una hilera de dos plantas por montículo en el centro del caballón, 66 667 plantas/ha. **AB:** Una hilera de una planta por montículo en el centro del caballón, 33 333 plantas/ha. **AC:** Dos hileras de dos plantas por montículo a los lados del caballón, 133 333 plantas/ha. **AD:** Dos hileras de una planta por montículo a los lados del caballón, 66 667 plantas/ha.

The variables measured included days to 50 % and 90 % flowering, number of pods per plant, pod length, number of seeds per pod, 100-seed weight, and grain and biomass yields per hectare. Data were analyzed using GenStat (12th edition). Means were separated using Fisher's protected least significant difference (LSD) test at a 5 % significance level. All graphs were generated using GraphPad Prism version 8.0 (GraphPad Software, Inc., San Diego, CA, USA).

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Results

The number of days to 50 % and 90 % flowering represents key phenological milestones in cowpea development and is critical for optimizing crop management decisions. These growth stages provide a temporal framework for scheduling essential agronomic practices, including weed management, pest control, and harvest planning. In this study, days to 50 % and 90 % flowering were systematically recorded.

Days to 50 % and 90 % flowering in the 2021 and 2022 cropping seasons

In 2021, no significant difference was observed between the number of days to 50 % flowering and the number of days to 90 % flowering. Additionally, days to 50 % flowering did not differ significantly among the planting designs (AA, AB, AC, and AD). Neither planting design nor plant density had a significant effect on the time required to reach 50 % flowering. In 2022, planting design AA differed significantly from planting design AC, and days to 50 % flowering differed significantly from days to 90 % flowering (Figure 2). The 50 % flowering stage was reached approximately 36 days after planting across all planting designs.

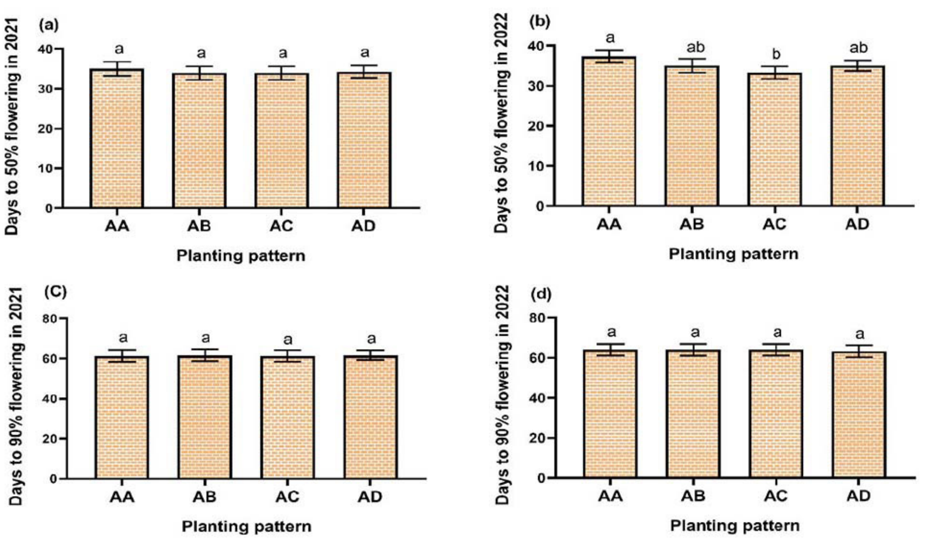

Figure 2. Days to 50 % and 90 % flowering of cowpea under four planting designs during the 2021 and 2022 cropping seasons at Manga, Ghana.

a: Days to 50 % flowering in 2021. **b:** Days to 50 % flowering in 2022. **c:** Days to 90 % flowering in 2021. **d:** Days to 90 % flowering in 2022. **AA:** Single row with two plants per hill at the center of the ridge. **AB:** Single row with one plant per hill at the center of the ridge. **AC:** Double row with two plants per hill at the side of the ridge. **AD:** Double row with one plant per hill at the side of the ridge. Values represent the mean standard deviation of four replicates. Means with the same lowercase letter are not significantly different between planting designs according to Duncan's multiple range test.

Figura 2. Días hasta el 50 % y el 90 % de floración del caupí en cuatro diseños de siembra durante las temporadas de cultivo 2021 y 2022 en Manga, Ghana.

a: Días hasta el 50 % de floración en 2021. **b:** Días hasta el 50 % de floración en 2022. **c:** Días hasta el 90 % de floración en 2021. **d:** Días hasta el 90 % de floración en 2022. **AA:** Una hilera con dos plantas por montículo en el centro del caballón. **AB:** Una hilera con una planta por montículo en el centro del caballón. **AC:** Dos hileras con dos plantas por montículo al lado del caballón. **AD:** Dos hileras con una planta por montículo al lado del caballón. Los valores representan la media ± desviación estándar de cuatro réplicas. Las medias con la misma letra minúscula no difieren entre los diseños de siembra según la prueba de rangos múltiples de Duncan.

During the 2022 cropping season, planting designs AA and AD did not differ significantly in the number of days to 50 % flowering, which occurred between 36 and 38 days across all plant densities. Similarly, the number of

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days to 90 % flowering did not differ significantly among planting designs (AA, AB, AC, and AD) in either 2021 or 2022. Across all planting designs, the 90 % flowering stage was reached between 60 and 65 days after planting.

Pod load and pod length per plant in the 2021 and 2022 cropping seasons

During the 2021 and 2022 cropping seasons, pod load showed notable variations among the assessed planting designs and plant densities (Figure 3). In this study, planting design AA (66 667 plants/ha) produced the highest pod load, at 45 pods per plant. In 2021, planting design AA (66 667 plants/ha) differed significantly from design AB (33 333 plants/ha), design AC (133 333 plants/ha), and design AD (66 667 plants/ha). Planting design AB (33 333 plants/ha) also differed from design AC (133 333 plants/ha) but did not differ from design AD (66 667 plants/ha). Across both cropping seasons, planting designs AB, AC, and AD recorded 41, 41, and 34 pods per plant, respectively, representing the lowest pod loads.

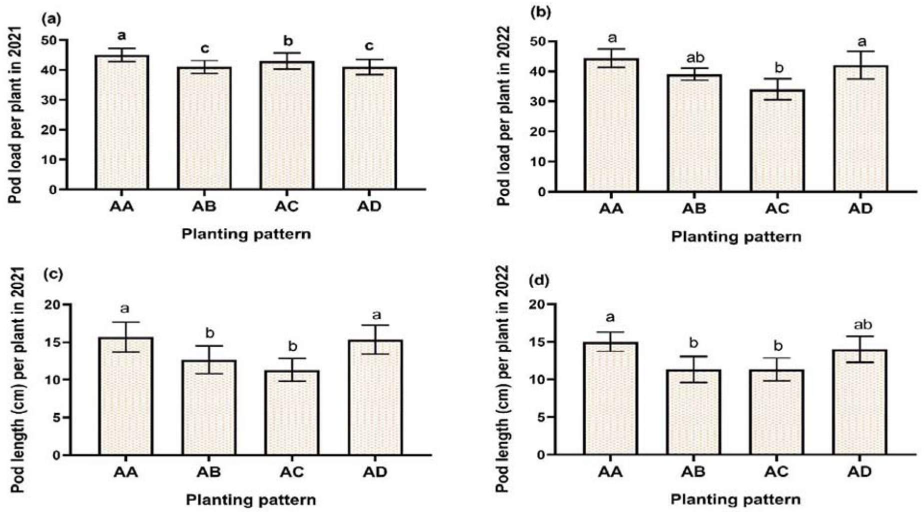

Figure 3. Pod load and pod length per plant of cowpea under four different planting designs during the 2021 and 2022 cropping seasons at Manga, Ghana.

a: Pod load per plant in 2021. **b:** Pod load per plant in 2022. **c:** Pod length per plant in 2021. **d:** Pod length per plant in 2022. **AA:** Single line with two plants per hill at the center of the ridge. **AB:** Single line with one plant per hill at the center of the ridge. **AC:** Double row with two plants per hill on both sides of the ridge. **AD:** Double row with one plant per hill on both sides of the ridge. Values represent the mean ± standard deviation of four replicates. Means with the same lowercase letter are not significantly different between planting designs according to Duncan's multiple range test.

Figura 3. Carga y longitud de vainas por planta de caupí en cuatro diseños de siembra diferentes durante las temporadas de cultivo de 2021 y 2022 en Manga, Ghana.

a: Carga de vainas por planta en 2021. **b:** Carga de vainas por planta en 2022. **c:** Longitud de vainas por planta en 2021. **d:** Longitud de vainas por planta en 2022. **AA:** una sola línea de dos plantas por montículo en el centro del caballón. **AB:** Una sola línea de una planta por Montículo en el centro del caballón. **AC:** Una doble hilera de dos plantas por montículo a los lados del caballón. **AD:** Una doble hilera de una planta por montículo a los lados del caballón. Los valores representan la media ± desviación estándar de cuatro réplicas. Las medias con la misma letra minúscula no difieren significativamente entre los diseños de siembra según la prueba de rangos múltiples de Duncan.

Pod length is a crucial factor for consumer acceptance of vegetable cowpeas, making it a useful selection metric. In 2021, pod length did not differ significantly between planting designs AA and AD, nor between AB and AC. Across both seasons, the longest and shortest pods measured 15 cm and 11 cm, respectively. In the 2021 and 2022 cropping seasons, there were statistical differences in pod length among the four planting designs. In 2021, planting design AA (66 667 plants/ha) differed from design AB (33 333 plants/ha) and AC (133 333 plants/ha) but

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did not from design AD (66 667 plants/ha). Likewise, planting designs AB (33 333 plants/ha) and AC (133 333 plants/ha) did not differ from each other, but both differed from design AD (66 667 plants/ha).

In the 2022 cropping season, variations were also observed between planting design AA (66 667 plants/ha) and designs AB (33 333 plants/ha), AC (133 333 plants/ha), and AD (66 667 plants/ha). Designs AB (33 333 plants/ha) and AC (133 333 plants/ha) did not differ, but both differed significantly from AD (66 667 plants/ha). The highest pod lengths were recorded under planting design AA (66 667 plants/ha), reaching 15.60 cm in 2021 and 15.00 cm in 2022.

The results indicate that the pod length did not differ significantly between planting designs AA (66 667 plants/ha) and AD (66 667 plants/ha). Designs AB (33 333 plants/ha) and AC (133 333 plants/ha) did not differ significantly in pod length in 2021 and 2022. However, design AA (66 667 plants/ha) differed slightly from design AD (66 667 plants/ha) in 2022.

Number of seeds per pod and 100-seed weight under different planting designs and densities in the 2021 and 2022 cropping seasons

The number of seeds per pod and 100-seed weight (Figure 4) varied significantly among the evaluated planting designs. Planting design AA consistently produced the highest number of seeds per pod, with 24 in 2021 and 20

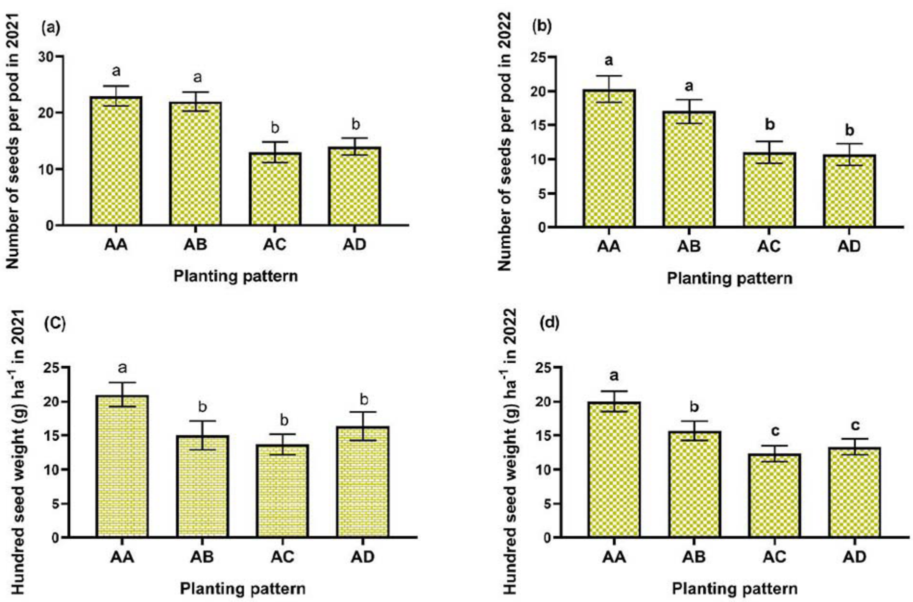

Figure 4. Number of seeds per pod and 100-seed weight of cowpea under four different planting designs during the 2021 and 2022 cropping seasons at Manga, Ghana.

a: Number of seeds per pod in 2021. **b:** Number of seeds per pod in 2022. **c:** 100-seed weight (g) in 2021. **d:** 100-seed weight (g) in 2022. **AA:** Single row with two plants per hill at the center of the ridge. **AB:** Single row with one plant per hill at the center of the ridge. **AC:** Double row with two plants per hill on both sides of the ridge. **AD:** Double row with one plant per hill on both sides of the ridge. Values represent the mean ± standard deviation over four replicates. Means with the same lowercase letter are not significantly different between planting designs according to Duncan's multiple range test.

Figura 4. Número de semillas por vaina y peso de 100 semillas de caupí en cuatro diseños de siembra diferentes durante las temporadas de cultivo de 2021 y 2022 en Manga, Ghana.

a: Número de semillas por vaina en 2021. **b:** Número de semillas por vaina en 2022. **c:** Peso de 100 semillas (g) en 2021. **d:** Peso de 100 semillas (g) en 2022. **AA:** Una sola hilera de dos plantas por montículo en el centro del caballón. **AB:** Una sola hilera de una planta por montículo en el centro del caballón. **AC:** Una doble hilera de dos plantas por montículo a los lados del caballón. **AD:** Una doble hilera de una planta por montículo a los lados del caballón. Los valores representan la media ± desviación estándar en cuatro réplicas. Las medias con la misma letra minúscula no difieren significativamente entre diseños de siembra según la prueba de rangos múltiples de Duncan.

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in 2022, representing an increase of up to 83 % across both seasons. In contrast, the lowest values were recorded in planting design AC, with 12 seeds per pod in 2021, and in both AC and AD, which recorded 11 seeds per pod in 2022. These designs showed reductions in seeds per pod of up to approximately 92 % relative to the maximum observed. A similar trend was observed for 100-seed weight, with planting design AA recording the highest values of 21 g in 2021 and 20 g in 2022, corresponding to an increase of up to 95 %. Conversely, planting designs AC and AD were associated with lower 100-seed weight.

Grain and biomass yield under different planting designs in the 2021 and 2022 cropping seasons

Grain and biomass yields varied among the evaluated planting designs (Figure 5). Planting design AA produced the greatest grain yields, at 1.50 and 1.43 t ha^{-1} in 2021 and 2022, respectively, while planting design AB produced the lowest grain yields, at 0.43 and 0.20 t ha^{-1} in 2021 and 2022, respectively. The highest biomass yields, 3.33 and 3.24 t ha^{-1}, were obtained from planting design AC in 2021 and 2022, respectively, while the lowest biomass yields, 1.22 and 1.16 t ha^{-1}, were obtained from planting design AB in the same years.

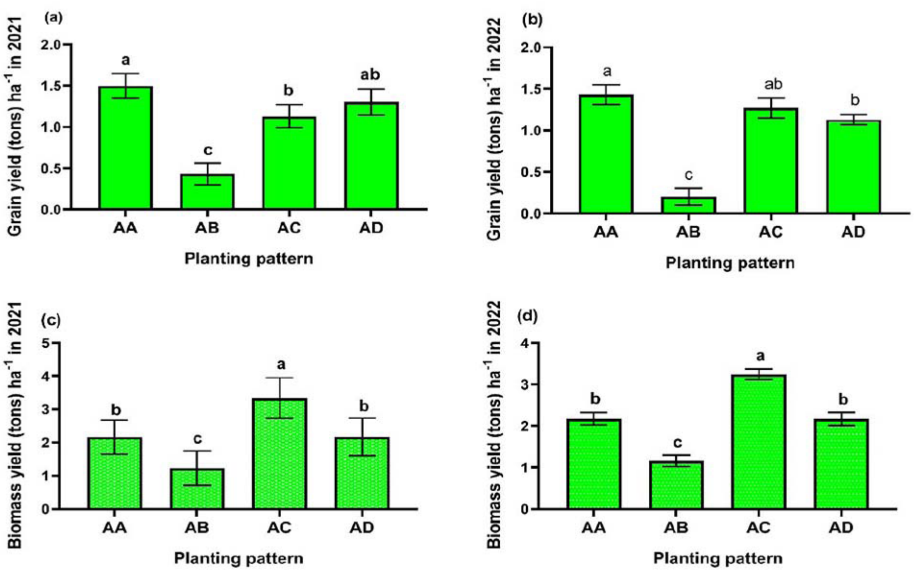

Figure 5. Grain and biomass yields (t ha^{-1}) of cowpea under four different planting designs during the 2021 and 2022 cropping seasons at Manga, Ghana.

a: Grain yield per ha in 2021. **b:** Grain yield per ha in 2022. **c:** Biomass yield per ha in 2021. d: Biomass yield per ha in 2022. **AA:** Single row with two plants per hill at the center of the ridge. **AB:** Single row with one plant per hill at the center of the ridge. **AC:** Double row with two plants per hill on both sides of the ridge. **AD:** Double row with one plant per hill on both sides of the ridge. Values represent the mean ± standard deviation over four replicates. Means with the same lowercase letter are not significantly different between planting designs according to Duncan's multiple range test.

Figura 5. Rendimientos de grano y biomasa (t ha^{-1}) de caupí en cuatro diseños de siembra diferentes durante las temporadas de cultivo de 2021 y 2022 en Manga, Ghana.

a: Rendimiento de grano por ha en 2021. **b:** Rendimiento de grano por ha en 2022. **c**: Rendimiento de biomasa por ha en 2021. d: Rendimiento de biomasa por ha en 2022. **AA:** Una sola hilera de dos plantas por montículo en el centro del caballón. **AB:** Una sola hilera de una planta por montículo en el centro del caballón. **AC:** Una doble hilera de dos plantas por montículo a los lados del caballón. **AD:** Una doble hilera de una planta por montículo a los lados del caballón. Los valores representan la media ± desviación estándar en cuatro réplicas. Las medias con la misma letra minúscula no difieren significativamente entre diseños de siembra según la prueba de rangos múltiples de Duncan.

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Discussion

The timing of 50 % and 90 % flowering is a critical factor in cowpea cultivation, guiding key management practices (Figure 2). The results showed that the timing of early and full flowering in cowpea was not significantly affected by the planting designs or densities evaluated. These findings are consistent with Satodiya et al. (2015), who reported that days to flowering were not affected by increasing cowpea density. The differences observed between planting design AB (33 333 plants/ha) and design AD (66 667 plants/ha) could be attributed to differences in planting designs and densities. The planting layout and cowpea plant population appeared to have influenced the timing of flowering.

The differences in pod loads can be attributed primarily to plant densities and the planting designs used. Optimized and low plant densities affected pod load, as observed in design AD. The finding that optimized plant density affects pod load was also reported by El Naim and Jabereldar (2010), as observed in this experiment. Planting design AA (66 667 plants/ha) facilitated higher pod formation in cowpea. The variations observed are largely due to plant density and planting design. These findings contradict those of Giridhar et al. (2020), who found no correlation between cowpea density and pod length.

The number of seeds per pod varied significantly across the four planting designs and densities during the 2021 and 2022 cropping seasons (Figure 4). Planting designs AA (66 667 plants/ha) and AB (33 333 plants/ha) produced more seeds per pod (20–23) in both seasons. This suggests that subsistence farmers can increase cowpea seed yield by using different planting designs with medium and low plant densities. These results conflict with the findings of El Naim and Jabereldar (2010), who reported that grain yield increases with optimal cowpea density.

The results indicate that both design AC (133 333 plants/ha) and design AD (66 667 plants/ha) had the lowest number of seeds per pod (11 and 15) in both cropping seasons. This is notable because, intuitively, one might expect the optimum density to maximize yield components such as seeds per pod. However, the data suggest otherwise, likely due to plant competition effects.

At the high plant density of design AC, individual plants compete intensely for resources such as light, nutrients, and water, which can limit flower and pod development and ultimately reduce the number of seeds per pod. Although more plants are present per hectare, the stress from competition causes each plant to produce fewer seeds. Although planting design AD, theoretically, should provide a balance between plant spacing and resource availability, the seed number per pod was still low. This suggests that planting design itself, not just the number of plants, plays a role.

Factors such as row arrangement, intra-row spacing, and canopy architecture could influence light interception, airflow, and pollination efficiency, thereby affecting seed formation. In other words, even at a moderate plant density that should allow for optimal seed development, an unfavorable planting pattern can constrain seed set. This is because a suitable planting design enhances nutrient uptake and improves the transfer of photosynthates from source to sink, resulting in higher accumulation of photosynthates in seeds.

This result aligns with previous research by Da Silva et al. (2019), who found that 100-seed weight increased with lower plant density. Planting design AC (133 333 plants/ha) recorded the lowest 100-seed weight, 12–13 g in both years, consistent with a reduction in 100-seed weight at this density. Different plant densities result in different 100-seed weights (Giridhar et al., 2020), which is consistent with the variations observed in this experiment. The highest grain yields, 1.50 and 1.43 t ha^{-1}, were obtained with planting design AA (66 667 plants/ha) in 2021 and 2022, whereas the lowest yields, 0.43 and 0.20 t ha^{-1}, were recorded with design AB (33 333 plants/ha) (Figure 5).

In this experiment, medium plant density (66 667 plants/ha), combined with the appropriate designs AA and AD, can optimize cowpea grain yield. This result conflicts with Kamara, Tofa et al. (2018), who found that higher plant density led to higher cowpea grain yields. The low grain yield recorded in design AC (133 333 plants/ha) can be attributed to low light availability, high shading effects, and nutrient depletion, as observed by Postma et al. (2021).

In the 2021 and 2022 cropping seasons, all the planting designs, AA (66 667 plants/ha), AB (33 333 plants/ha), AC (133 333 plants/ha), and AD (66 667 plants/ha), were compared. The results showed that planting designs and densities were primarily responsible for the observed variations. While Satodiya et al. (2015) reported that plant density has no effect on cowpea grain yield, the results of this experiment contradict that finding.

Comparing the cropping seasons of 2021 and 2022, only planting designs AC (133 333 plants/ha) and AD (66 667 plants/ha) showed significant differences in grain yield. Plant density affected grain yield and yield components in this research. This finding aligns with Tehulie and Yimam's (2020) assertion that the number of plants per unit area influences plant size, yield components, and ultimately seed yield. Therefore, in cowpea, plant density and planting design can positively or negatively affect grain yields and yield attributes.

Low plant density promotes aeration and enhances the plant canopy to maximize the photosynthetic rate, ultimately resulting in higher yields (Tehulie & Yimam, 2020). However, this contradicts the findings of this research, as the lowest density, 33 333 plants/ha, produced the lowest grain yield in this experiment. While there was no statistically significant difference in biomass yield between the 2021 and 2022 cropping seasons, there were notable differences between planting densities and designs (Figure 5).

Similarly, design AB (33 333 plants/ha) was compared with design AC (133 333 plants/ha) and design AD (66 667 plants/ha). The highest biomass yields, 3.33 and 3.24 t ha^{-1}, were obtained with planting design AC in both cropping seasons, while the lowest biomass yields, 1.16 and 1.22 t ha^{-1}, were recorded with planting design AB.

This indicates that cowpea biomass yield was maximized by combining the ideal plant density with the appropriate planting design. This cropping technology can be used by livestock farmers to increase biomass for animal feed. In this study, employing the ideal plant density can boost biomass yield, which is consistent with the findings of Kamara, Tofa et al. (2018). This study supports the hypothesis that cropping systems maximizing plant density, as proposed by Makoi et al. (2009), may increase N_2 fixation in cowpeas and contribute to soil nitrogen in Africa.

Conclusions

Adapting cropping practices that enhance cowpea grain and biomass yields is essential. Optimizing plant density and planting design can significantly improve yield and its components. Planting design AA (66 667 plants/ha) is recommended to maximize the number of seeds per pod, 100-seed weight, and grain yield, while design AC (133 333 plants/ha) is recommended for biomass production. Smallholder farmers are encouraged to adopt climate-smart, intensified cropping practices to improve productivity.

Conflict of interest

The authors declare no conflict of interest

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