Open Access Library Journal
2024, Volume 11, e11166
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Evaluation of Some Cowpea Genotypes for Maize-Cowpea Intercropping System in the Sudan Savannah Ecology of Ghana

Aziiba Emmanuel Asibi[1,2*], Richard Dormatey[3], Julius Yirzagla[1], Listowel Aditwin Akologo[4], Issah Sugri[5], Peter Quandahor[5], Francis Kusi[5], Muktharu Zakaria[1], Patrick Attamah[1], Peter Anabire Asungre[1], Lamini Salim[1], Anslem Bawayelaazaa Nyour[5]

[1]Council for Scientific and Industrial Research, Savanna Agricultural Research Institute (CSIR-SARI), Bawku, Ghana
[2]Department of Animal Science, University of California, Davis, USA
[3]Council for Scientific and Industrial Research, Crops Research Institute (CSIR-CRI), Kumasi, Ghana
[4]Gbewaa College of Education, Pusiga, Ghana
[5]Council for Scientific and Industrial Research, Savanna Agricultural Research Institute (CSIR-SARI), Tamale, Ghana
Email: *aziibason4u@gmail.com

How to cite this paper: Asibi, A.E., Dormatey, R., Yirzagla, J., Akologo, L.A., Sugri, I., Quandahor, P., Kusi, F., Zakaria, M., Attamah, P., Asungre, P.A., Salim, L. and Nyour, A.B. (2024) Evaluation of Some Cowpea Genotypes for Maize-Cowpea Intercropping System in the Sudan Savannah Ecology of Ghana. *Open Access Library Journal*, **11**: e11166.
https://doi.org/10.4236/oalib.1111166

Received: March 30, 2024
Accepted: September 15, 2024
Published: September 18, 2024

Abstract

For smallholder farmers in sub-Saharan Africa, determining which cowpea genotype is most promising for intercropping systems involving maize and cowpeas can be difficult. It is challenging for smallholder farmers in northern Ghana to identify the most promising cowpea genotype to combine with maize. In the 2021 and 2022 cropping seasons, twenty-nine cowpea genotypes were grown from July to October at the Council for Scientific and Industrial Research—Savannah Agricultural Research Institute research field in Manga, both as sole crops and as intercrops with maize. Days to 50% flowering—days after planting (DAP), pod load per plant, days to 95% pod maturity—days after planting (DAP), and cowpea grain, and biomass yields per hectare were among the data gathered. The findings demonstrated significant genotype-to-genotype variability in days to 50% flowering, pod load, days to 95% pod maturity, grain, and biomass yields in both cropping systems. Days to 50% flowering, days to 95% pod maturity and genotype-specific grain and biomass yields were not always correlated. This may be caused by the various cultivation methods and the unique genotypes' genetic makeup. As a result, the study offers a basic comprehension of the essential traits of some cowpea genotypes, which could be helpful for upcoming breeding initiatives that focus on intercropping systems. According to the study, intercropping can maximize the grain and biomass yields of some cowpea genotypes in an environmentally sustainable way. Maize and cowpea are more competitive when intercropped than planted sole, intercropping can reduce grain and biomass yields. In the intercropping system, genotypes with land equivalency ratios greater than one show optimal use of available environmental resources. To enhance any traits that may be lacking, the genotypes can be crossed.

Subject Areas

Agronomy, Ecology, Plant Breeding

Keywords

Cropping System, Cowpea, Genotypes, Sustainable Cropping, Smallholder Farmers

1. Introduction

In many sub-Saharan West African households, cowpeas, or *Vigna unguiculata* (L.) Walpers, are a major source of plant protein and an important legume food crop. Africa produces and consumes between 6.1 and 5.2 million tons of cowpeas annually on a global scale [1] [2]. The grain meets a large portion of the protein needs of rural impoverished people who lack the resources to buy animal protein because it contains between 23 and 25 percent protein [3]. Approximately 70% of cowpea production takes place in West and Central Africa's drier Savanna and Sahelian regions [4] [5]. In Ghana, cowpeas are currently the second most important food legume after groundnuts in terms of cultivated area, produced quantity, and consumption [6]. Because it produces grain and dry matter that can be used as animal feed during the dry season, the crop is very important to the people of northern Ghana.

Cropping system characteristics have the potential to modify the life cycle of pests and weeds and to fundamentally alter the abiotic and biotic features of an agroecosystem [7] [8], which could limit production. In Northern Ghana, farmers use a variety of cropping systems to boost productivity and sustainability. Intercropping is the practice of growing two or more crops simultaneously in the same field. In Northern Ghana, intercropping plays a significant role in the cropping system. According to [9] [10], intercropping can shorten the critical growth period of weeds, serve as a weed control, and decrease the growth and fecundity of late-emerging weeds by increasing light interception by the weakly competitive component. The land equivalent ratio values of intercropping systems showed that intercropping was more productive than sole growing maize. They also showed that intercropping could improve soil fertility conservation and increase the amount of nutrients in the soil compared to sole growing maize [11]. Intercropping systems have the potential to be adopted in low-input farming systems where chemical weed control options are limited or nonexistent due to their apparent increased competitiveness [12]. Africa frequently engages in cereal-legume intercropping, particularly with maize, as it maximizes the use of labor and land while securing food production by lowering the risk of crop yield loss [13]. Cowpeas can be grown as an intercrop with cereals like sorghum (*Sorghum bicolor* (L.) Moench) or pearl millet (*Pennisetum glaucum* (L) R.BR.), but they are also occasionally grown as a sole crop or as an intercrop with maize [14]. Intercropping may be the most climate-smart agricultural practice in the cropping system due to the trend of climatic variables in Northern Ghana. Farmers may be forced to change their crop choice in order to adapt to or cope with such changes in climatic conditions due to changing patterns of climatic variables, such as rainfall and temperature [15]. Through intercropping, smallholder farmers—particularly those who grow sole legume crops in northern Ghana and other similar agro-ecologies in West Africa—could reduce production risk and boost revenue [16]. Higher grain yields are obtained from mixing cereals and legumes than from growing each crop alone [17]. It has been demonstrated that cowpea contributes roughly 240 kg N/ha, with subsequent crops in rotation on infertile soils benefiting from an additional 60 - 70 kg N/ha [18].

Low cowpea productivity is a result of poor production techniques, such as adaptability and cultivar selection [19]. The four main factors that make intercropping better than monoculture are soil conservation, resistance to lodging, increased yield, and weed control [7]. One important factor influencing cowpea production and consumption in Ghana is varietal preference [14]. While cowpea farmers in northern Ghana have access to a variety of genotypes, smallholder farmers lack the knowledge necessary to select the most promising genotypes for intercropping maize and cowpea. The challenge of selecting the ideal cowpea genotype for intercropping presents itself to them. The ability of farmers to intercrop and the production of cowpea with farmer-consumer preferences for grains could encourage more cowpea cultivation in Ghana. Understanding cowpea genotypes with promise and production barriers will aid in creating cultivable varieties. The purpose of this study was to identify the most promising genotypes of cowpeas for smallholder farmers in the northern region of Ghana and other similar ecologies to use in maize-cowpea intercropping.

2. Materials and Methods

2.1. Location and Planting Materials

At Manga (11˚01N, 0˚16 W), from July to October of the 2021 and 2022 cropping seasons, twenty-nine (29) cowpea genotypes (KBC-9, KT-Benga, TC-901, Narocowpea-5, Secow-5T, Secow-1T, Nizwe, Narocowpea-4, THIEY, UAM14-126-L33, Apagbala, Zurazam, Secow-4W, Gujaratcowpea-5, CK1-Padi tuya, Secow-3B, SAM, Leona, IT99K573-1-1, Narocowpea-3, Plantlobia-1, Narocowpea-6, IT-38956-1, CK-2, CK4-W2, Gujaratcowpea-3, Secow-2W, Agyenkwa, and Narocowpea-2) (**Table 1**) were evaluated in sole and intercropped systems.

Table 1. Sole and intercropped cowpea genotypes in 2021 and 2022 cropping seasons.

Narocowpea-3	Secow-2W	Narocowpea-2	IT-38956-1	PlantLobia-1
Leona	Gujaratcowpea-5	UAM14-126-L33	TC-901	Apagbala
Secow-1T	IT99K573-1-1	CK-2	Gujaratcowpea-3	KBC-9
Zurazam	CK4-W2	Secow-4W	Secow-3B	Aygenkwa
Narocowpea-4	Narocowpea-5	Nizwe	CK1-Padi tuya	THIEY
KT-Benga	SAM	Secow-5T	Narocowpea-6	

2.2. Experimental Design and Treatments

A tractor was used for light harrowing, and then ridged with bullock ridger. On July 1st, maize was planted, and the 29 genotypes of cowpea were interplanted and sole cropped two weeks later in a Randomized Complete Block Design (RCBD) with four replications. In both cropping systems, three seeds were planted per hill, and the plants were subsequently thinned to two per stand. For maize-cowpea intercropping, the spacing was 75 × 40 cm, and for sole cowpea cropping, it was 75 × 20 cm. Fertilizer N.P.K., 90 kg N ha^{-1}, and 40% urea were applied as top dressing to the maize-cowpea intercrop as a basal fertilizer. Muriate of potash was applied to the sole cowpea at a rate of 40 kg K ha^{-1}. The hand hoe was used to reshape and ridge tie to prevent soil erosion in both cropping systems. Manual control of weeds was applied when needed. EMA STAR was used to control Fall Army Worm, while K-Optimal (Cyhalothrin 15 g/l + Acetamiprid 20; EC) at 500 ml ha^{-1} was sprayed three times to control insect pests during the vegetative, flowering, and podding stages.

2.3. Data Collection and Statistical Analysis

Days to 50% flowering—days after planting (DAP), days to 95% pod maturity-days after planting (DAP), average pod load per plant, and grain and biomass yields per hectare were among the data gathered.

Chicago, IL, USA's GenStat 12th Edition was used to analyze the data. Fisher's protected LSD at 5% was used to separate the means. Using the formula developed by [20], the land equivalent ratio (LER) was computed to compare the productivity of the intercrops to that of the sole crops as in [20].

$$\text{LER} = \frac{\text{Yield of maize intercrop}}{\text{Yield maize sole crop}} + \frac{\text{Yield legume intercrop}}{\text{Yield legume sole crops}} = \text{Equation 1}$$

Rainfall is typically unimodal, with an average yearly total of approximately 1200 mm, starting in mid-May and ending in early October. The remaining months of the season are cloudy and dry. The average yearly temperature is measured at 27.3˚C, with March through May being the hottest months. The Food and Agriculture Organization of the United Nations has designated the well-drained soil as ferric luvisol. It is brown, fine sandy loam, with low organic matter.

3. Results

3.1. Cowpea Genotypes Reaching 50% Flowering at 40 - 45 Days after Planting in the Sole and Intercropping Systems

Days to flowering varied significantly at ($p < 0.05$) depending on the genotype and cropping system. In both the sole and intercropping systems, the extra early maturing cowpea genotypes took 40 to 45 days to reach 50% flowering. In the sole and intercropping systems, the genotypes KT-Benga, Gujaratcowpea-5, KBC-9, Gujarat cowpea-3, Aygenkwa, Narocowpea-4, Narocowpea-5, and Narocowpea-6 were the extra early maturing genotypes that reached 50% flowering at 40 to 45 days (Figure 1).

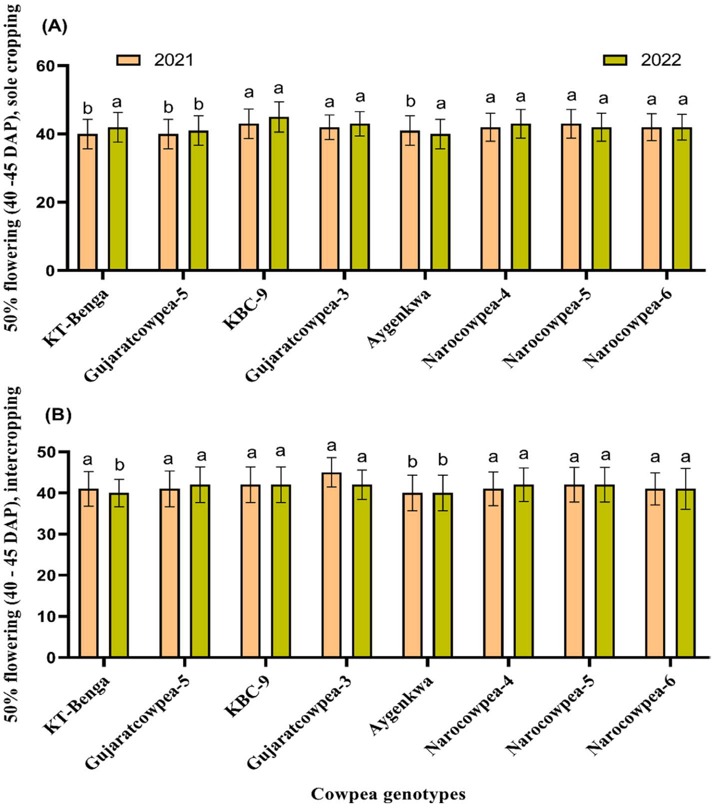

Figure 1. Days to 50% flowering of cowpea genotypes in 2021 and 2022 cropping seasons: (A) sole cropping (40 - 45 DAP), (B) intercropping (40 - 45 DAP). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters show significant differences by Fisher's protected LSD ($p \leq 0.05$).

3.2. Cowpea Genotypes of 95% Pod Maturity at (50 - 60 DAP) in Sole Cropping and (61 - 65 DAP) in Intercropping in 2021 and 2022 Cropping Seasons

Thirteen (13) of the genotypes out of the twenty-nine (29) genotypes evaluated attained 95% pod maturity between 50 - 60 days after planting in the sole cropping system in 2021 and 2022 cropping seasons (Figure 2). It took 61 - 65 days for the same genotypes to reach 95% pod maturity in the intercropping system in 2021 and 2022 cropping seasons.

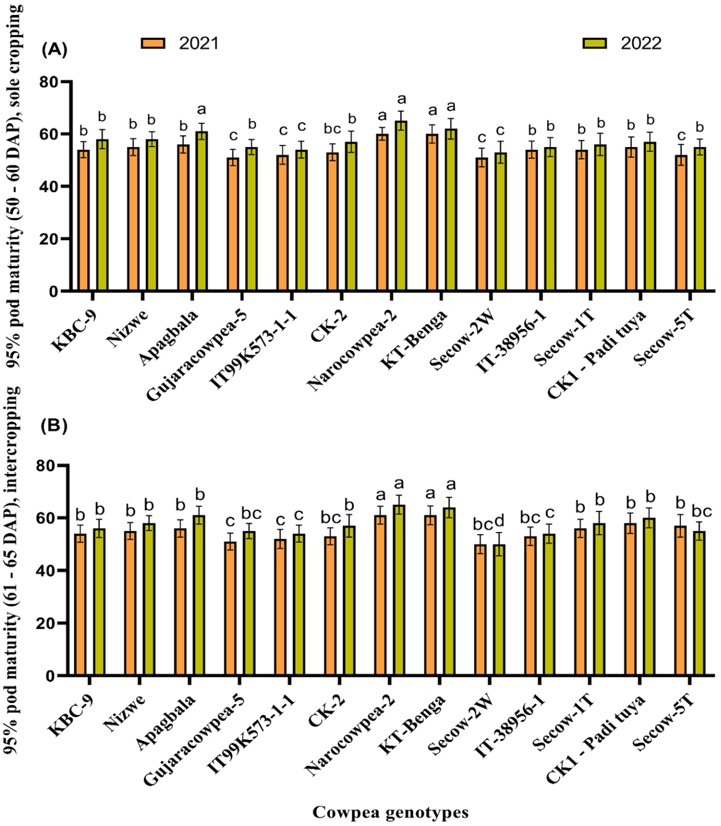

Figure 2. Pod maturity at 95% of cowpea genotypes in the 2021 and 2022 cropping seasons: (A) sole cropping (50 - 60 DAP), (B) intercropping (61 - 65 DAP). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters show significant differences by Fisher's protected LSD ($p \leq 0.05$).

3.3. Effects of Sole and Intercropping on Pod load of Cowpea Genotypes in the 2021 and 2022 Cropping Seasons

Pod load per plant was one of the key factors considered during the screening process. Pod load varied between genotypes in the sole and intercropping systems, and in both 2021 and 2022 cropping seasons (Figure 3(A) and Figure 3(B), Figure 4(A) and Figure 4(B), and Figure 5(A) and Figure 5(B)).

3.4. Evaluation of Genotypes Grain and Biomass Yields in Sole and Intercropping Systems

One of the most important factors in this screening was grain and biomass yields. Therefore, the potential yields for each genotype in intercropping and sole cropping were determined. The highest grain yields of the genotypes (Figure 6) were calculated to be between 1.00 - 1.27 and 0.50 - 1.02 tons per ha^{-1} in sole and intercropping, respectively. In both years, the highest biomass yield in the sole and intercropping systems differed between the genotypes. It varied between 2.56 - 3.79 t/ha and 1.00 - 1.8 t/ha in sole cropping and 1.86 - 4.03 t/ha and 1.00 - 2.55 t/ha in the intercropping systems in all years (Figure 7(A) and Figure 7(B), Figure 8(A), and Figure 8(B)).

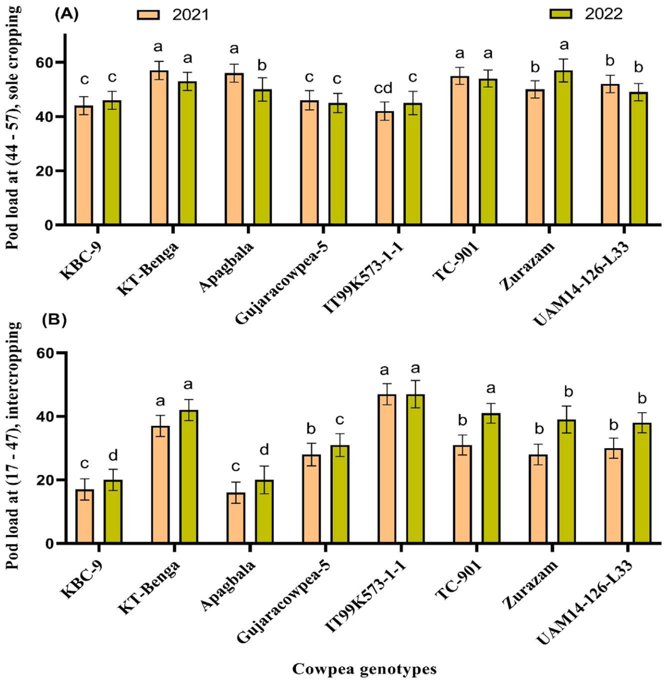

Figure 3. Pod load of cowpea genotypes in the 2021 and 2022 cropping seasons: (A) sole cropping (44 - 57), (B) intercropping (17 - 47). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters show significant differences by Fisher's protected LSD ($p \leq 0.05$).

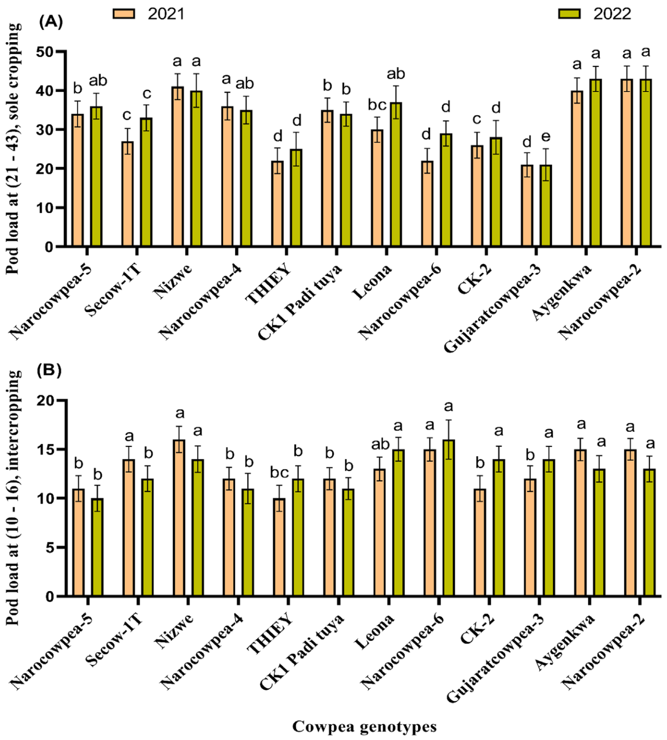

Figure 4. Pod load of cowpea genotypes in the 2021 and 2022 cropping seasons: (A) sole cropping (21 - 43), (B) intercropping (10 - 16). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters show significant differences by Fisher's protected LSD ($p \leq 0.05$).

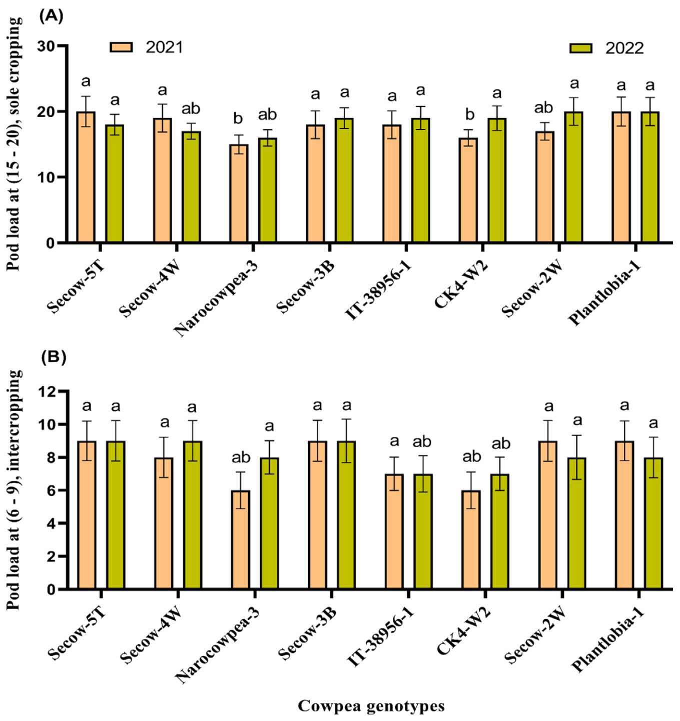

Figure 5. Pod load of cowpea genotypes in the 2021 and 2022 cropping seasons: (A) sole cropping (15 - 20), (B) intercropping (6 - 9). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters indicate a significant difference by Fisher's protected LSD ($p \le 0.05$).

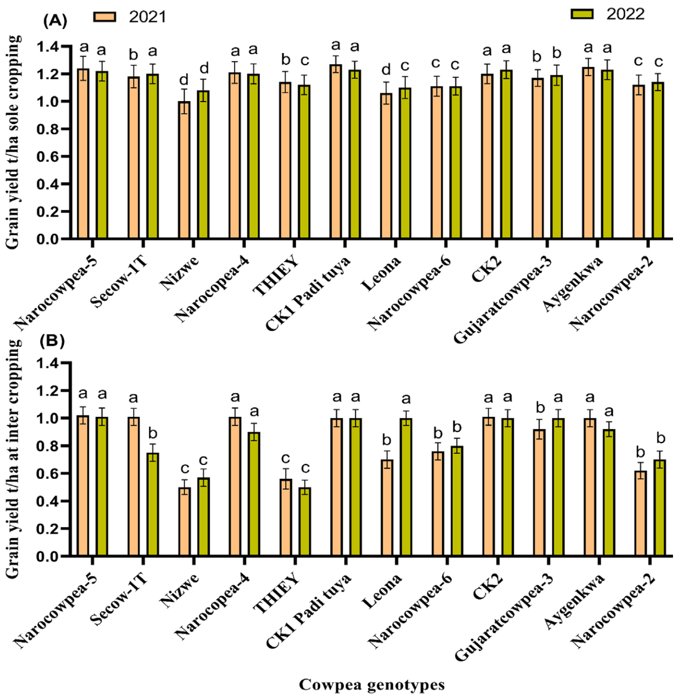

Figure 6. Grain yield of genotypes (t/ha) in 2021 and 2022 sole and intercropping systems (A) sole cropping (1.00 - 1.27), (B) intercropping (0.50 - 1.02). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters indicate a significant difference by Fisher's protected LSD ($p \le 0.05$).

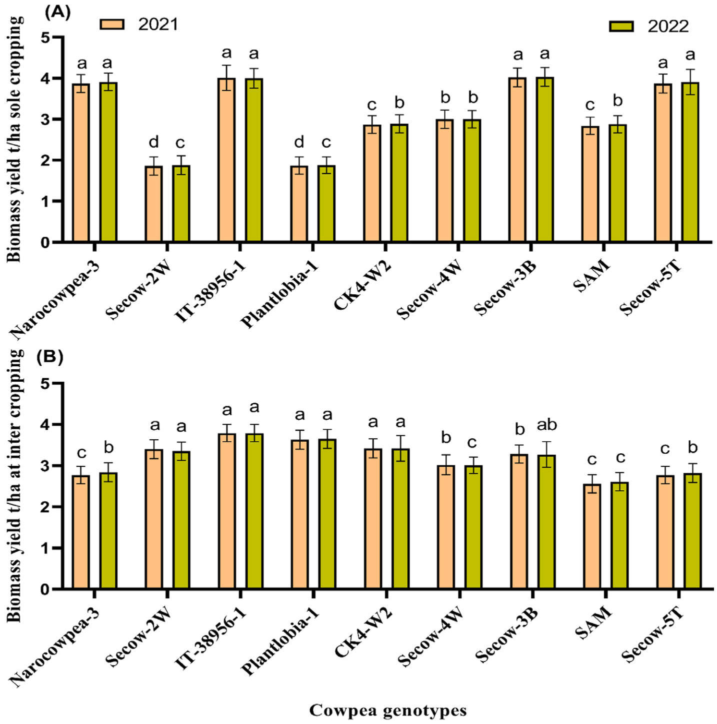

Figure 7. Biomass yield (t/ha) of cowpea genotypes in 2021 and 2022 sole and inter cropping Systems: (A) sole cropping (1.86 - 4.03), (B) intercropping (2.56 - 3.79). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters indicate a significant difference by Fisher's protected LSD ($p \leq 0.05$).

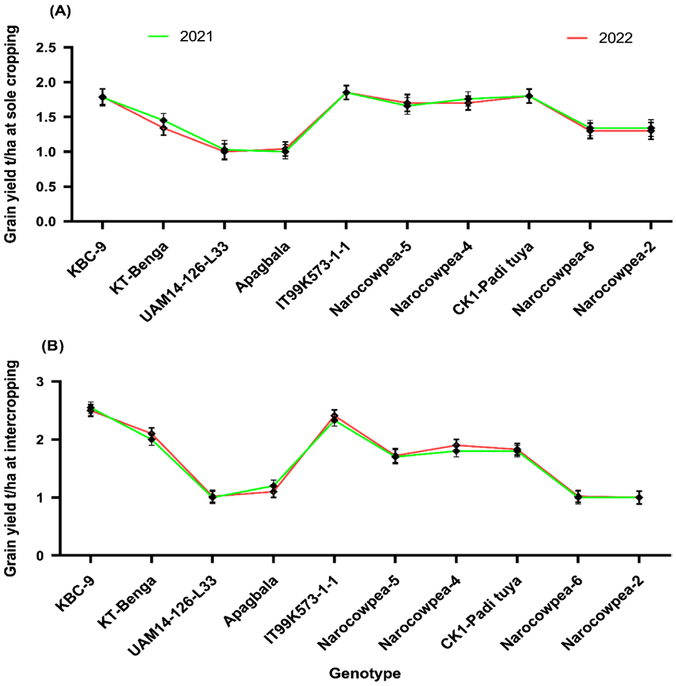

Figure 8. Grain yield (t/ha) of the cowpea genotypes studied: (A) sole cropping (1.00 - 1.85), (B) intercropping (1.00 - 2.55). The values indicate the mean of 4 replicates ± standard deviation (SD). Bars with different lower-case letters indicate a significant difference by Fisher's protected LSD ($p \leq 0.05$).

The land equivalent ratios (LER) of the genotypes listed below were below 1.00, Narocowpea-3, Secow-2W, IT-38956-1, Plantlobia-1, CK4-W2, Secow-4W, Secow-3B, SAM and Secow-5T (**Figure 9**). They therefore do not indicate good utilization of soil resources. All other genotypes, with the exception of those mentioned above, had a LER value of 1.00 and above, indicating good utilization of resources.

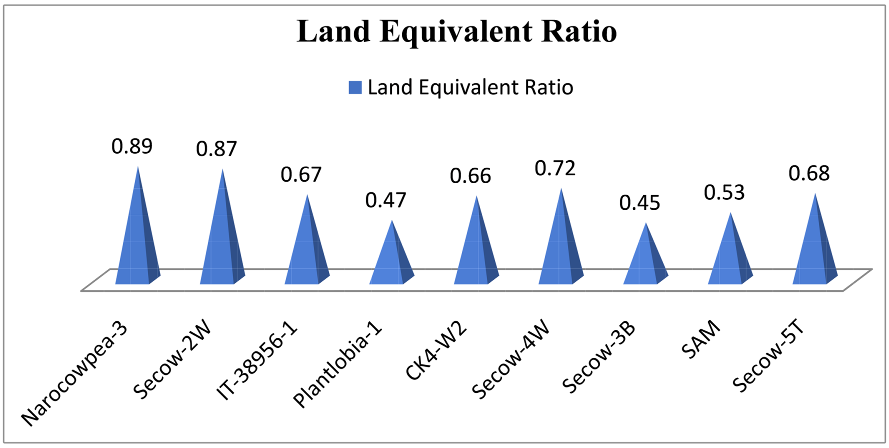

Figure 9. Genotypes with lowest land equivalent ratios.

4. Discussions

In the 2021 and 2022 sole and intercropping systems, the genotypes KT-Benga, Gujaratcopea-5, KBC-9, Gujaratcowpea-3, Aygenkwa, Narocowpea-4, Narocowpea-5, and Narocowpea-6 reached 50% flowering between 40 - 45 days after planting (**Figure 1**). According to the description by Owusu *et al.* [21], these genotypes (KT-Benga, Gujaratcopea-5, KBC-9, Gujaratcowpea-3, Aygenkwa, Narocowpea-4, Narocowpea-5, and Narocowpea-6) can be classified as extra-early genotypes, while the remaining twenty-one (21) genotypes in this experiment are medium or late maturing. In 2021 and 2022 sole and intercropping systems, the genotypes, KT-Benga, Gujaratcopea-5, and Aygenkwa had significant differences ($p < 0.05$) in their days to 50% flowering. However, in the sole cropping system in 2021 and 2022, only KT-Benga and Aygenkwa had significant differences ($p < 0.05$) in their days to 50% flowering. Only the genotype Aygenkwa had significant difference at ($p < 0.05$) in its days to 50% flowering in 2021 and 2022 intercropping system. The genotypes KT-Benga, Gujaratcopea-5, KBC-9, Gujaratcowpea-3, Narocowpea-4, 5, and 6 had no significant differences ($p > 0.05$) in days to 50% flowering in 2022 intercropping system, but significantly differed ($p < 0.05$) to Aygenkwa in days to 50% flowering in the same year and cropping system. The early flowering (40 - 45) days in the above genotypes might shorten their productive cycles and help the genotypes to escape or prevent late attack of pests and diseases, or drought in their reproductive cycles. Shortening the life cycle of plants help check pest and disease outbreaks, and unfavorable temperatures in the flowering and podding stages as postulated by Song *et al.* [22].

Pod maturity at 95% was reached between 50 - 60 days after planting in 2021 and 2022 sole cropping system in the genotypes KBC-9, Nizwe, Apagbala, Gujaratcowpea-5, IT99K573-1-1, CK-2, Narocowpea-2, KT-Benga, Secow-2W, IT-38956-1, Secow-1T, CK1-Padi tuya, and Secow-5T (**Figure 2**). In 2021 and 2022 sole cropping system, the genotypes Apagbala, Gujaratcowpea-5, CK-2, and Secow-5T had significant differences ($p < 0.05$) in their 95% pod maturity. Though, these genotypes KBC-9, Nizwe, IT-38956-1, Secow-1T, and CK1-Padi tuya had no significant differences ($p > 0.05$) in 95% pod maturity in 2021 and 2022 sole cropping, they however, were significantly different ($p < 0.05$) to the genotypes IT99K573-1-1, CK-2, Narocowpea-2, KT-Benga, and Secow-2W in the 2021 and 2022, 95% pod maturity in the sole cropping system. The same genotypes took 61 - 65 days to reach 95% pod maturity in the intercropping system in 2021 and 2022 cropping seasons. In 2021 and 2022 intercropping system, only the genotypes Gujaratcowpea-5, CK-2, Secow-2W, IT-38956-1, and Secow-5T had significant differences ($p < 0.05$) in their 95% pod maturity. These genotypes also, had significant differences ($p < 0.05$) to the genotypes KBC-9, Nizwe, Apagbala, IT99K573-1-1, Narocowpea-2, KT-Benga, Secow-1T, and CK1 - Padi tuya in 2021 and 2022, 95% pod maturity in the intercropping system. In comparison, only the genotype Apagbala, Gujaratcowpea-5, Secow-2W, IT-38956-1, and Secow-5T had significant differences ($p < 0.05$) in their 95% pod maturity in 2021 and 2022 seasons and cropping systems. Intercropping delayed the days to 95% pod maturity (61 - 65) days of the genotypes KBC-9, Nizwe, Apagbala, Gujaratcowpea-5, IT99K573-1-1, CK-2, Narocowpea-2, KT-Benga, Secow-2W, IT-38956-1, Secow-1T, CK1-Padi tuya, and Secow-5T genotypes, which could be the shading effect of the maize on physiological maturity as explained in [23]. Singh *et al.* [24], assumed that genotypes that require more than 55 days to reach 95% pod maturity are classified as late or medium maturing genotypes.

The genotypes KBC-9, KT-Benga, Apagbala, Gujaratcowpea-5, IT99K573-1-1, TC-901, Zurazam, and UAM14-126-L33 had the highest pod load ranging between 44 - 57 pods per plant in the 2021 and 2022 sole cropping system, followed by Narocowpea-5, Secow-1T, Nizwe, Narocowpea-4, THIEY, CK1-Padi tuya, Leona, Narowcowpea-6, CK-2, Gujaratcowpea-3, Aygenkwa, and Narocowpea-2 with 21 - 43 pods per plant. The average number of pods per plant further declined in the sole cropping system (15 - 20) pods in 2021 and 2022 in the genotypes Secow-5T, Secow-4W, Narocowpea-3, Secow-3B, IT-38956-1, CK4-W2, Secow-2W, and Plantlobia-1. In the intercropping system in 2021 and 2022, the genotypes KBC-9, KT-Benga, Apagbala, Gujaratcowpea-5, IT99K573-1-1, TC-901, Zurazam, and UAM14-126-L33 recorded pod loads of (17 - 47). The genotypes, Narocowpea-5, Secow-1T, Nizwe, Narocowpea-4, THIEY, CK1-Padi tuya, Leona, Narocowpea-6, CK-2, Gujaratcowpea-3, Aygenkwa, and Narocowpea-2 in the 2021 and 2022 intercropping loaded pods between 10 - 16 per plant. Pod load per plant continued to decline in the intercropping system in the genotypes Secow-5T, Secow-4W, Narocowpea-3, Secow-3B, IT-38956-1, CK4-W2, Secow-2 W, and Plantlobia-1, which recorded the least pods of (6 - 9) pods in 2021 and 2022.

In the 2021 and 2022 (**Figure 3(A)** and **Figure 3(B)**, **Figure 4(A)** and **Figure 4(B)**, and **Figure 5(A)** and **Figure 5(B)**) sole cropping genotypes with pod load (44 - 57); only the genotypes Apagbala, IT99K573-1-1, and Zurazam had significant differences ($p < 0.05$) in their pod load. Moreover, the genotypes KBC-9, Apagbala, Gujaratcowpea-5, and TC-901 of pod load (17 - 47) in intercropping system in 2021 and 2022 had significant differences ($p < 0.05$). By comparing the 2021 and 2022 genotypes with pod load of (44 - 57) in sole cropping and (17 - 47) in intercropping system, only the genotypes KBC-9, Apagbala, Gujaratcowpea-5, IT99K573-1-1, TC-901, and Zurazam had significant differences ($p < 0.05$). It is worth noting that, only the genotype IT99K573-1-1 among these gave higher yield in the intercropping system. Pod load (44 - 57) of the sole cropped genotypes declined in 2021 and 2022 to (21 – 47) (Narocowpea-5, Secow-1T, Nizwe, Narocowpea-4, THIEY, CK1-Padi tuya, Leona, Narocowpea-6, CK-2, Gujaratcowpea-3, Aygenkwa, and Narocowpea-2) with significant differences ($p < 0.05$). The genotypes, Narocowpea-5, Narocowpea-4, Leona, CK-2, and Gujaratcowpea-3 significantly differed ($p < 0.05$) in their pod load in the (21 - 43) pod load group in 2021 and 2022 sole cropping, while the rest of the genotypes in the same pod group remained the same. The 21 - 43 pod load group of genotypes in the sole cropping system had their pod load also declined to 10 - 16 pods in the intercropping system in the 2021 and 2022 seasons. There were significant differences ($p < 0.05$) among the genotypes Secow-1T, THIEY, Leona, CK-2, and Gujaratcowpea-3 in the 2021 and 2022 cropping seasons. Genotypes with the pod load of 21 - 43 and 10 - 16 pods per plant in sole and intercropping systems in 2021 and 2022, only the genotypes CK1-Padi tuya, Aygenkwa, and Narocowpea-2 had significant differences ($p < 0.05$). Further evaluation of the genotypes revealed that, the 15 - 20 pod groups in sole cropping in 2021 and 2022, only the genotypes Secow-4W, Narocowpea-3, CK4-W2, and Secow-2W were significantly different at ($p < 0.05$). It also clearly demonstrated that, same genotypes with 15 - 20 pods per plant in the sole cropping system declined to 6 - 9 pods in the intercropping system in the same years. In the intercropping system in 2021 and 2022, only the genotypes Narocowpea-3, IT-38956-1, CK4-W2, and Secow-2W were significantly different in having the least pods. Comparing the 2021 and 2022 sole and intercropping systems of genotypes 15 - 20 and 6 - 9 pods respectively, only the genotypes Secow-4W, Narocowpea-4, Narocowpea-3, IT-38956-1, CK4-W2, and Secow-2W were also significantly different. It was evident that, intercropping reduces pod load in many of the evaluated genotypes. According to Nelson *et al.* [25], the differences in pod load per plant can be caused by the different cropping systems. While monocropping promotes a higher pod load per plant, intercropping can reduce the pod load of cowpea genotypes. However, genotypes, such as KT-Benga, IT99K573-1-1, and Narocowpea-6 can be considered suitable genotypes for intercropping cowpea with maize. It can be deduced from this experiment, that the pod load per plant can be maintained to almost 50% when intercropped with maize (**Figure 3**). These genotypes are therefore good candidates for further breeding work to improve their pod load trait and make them more suitable for maize-cowpea intercropping systems.

One of the most important factors in this screening was grain yield. Therefore, the potential yields for each genotype in the intercropping and sole cropping systems were determined. The highest grain yields recorded were between 1.00 - 1.27 tons per ha^{-1} in the genotypes Narocowpea-5, Secow-1T, Nizwe, Narocowpea-4, THIEY, CK1-Padi tuya, Leona, Narocowpea-6, CK2, Gujaratcowpea-3, Aygenkwa, and Narocowpea-2 in the sole cropping system. Genotypes that recorded lower grain yields, thus below 1.00 and 0.50 tons in sole and intercropped systems respectively, were deemed not good and therefore not discussed. In the 2021 and 2022 seasons in the sole cropping system, only the genotypes Secow-1T, THIEY, and Leona were considered to have significant differences ($p < 0.05$) in their grain yields. They however, significantly differed to the other genotypes in the same cropping system and season. The genotypes Narocowpea-5, Secow-1T, Nizwe, Narocowpea-4, THIEY, CK1-Padi tuya, Leona, Narocowpea-6, CK2, Gujaratcowpea-3, Aygenkwa, and Narocowpea-2 yields declined to 0.50 - 1.02 in the intercropping system in 2021 and 2022 seasons. In this same intercropping system in 2021 and 2022, only the genotypes Secow-1T, Leona, and Gujaratcowpea-3 were recorded having significant differences in grain yields. Comparing the 2021 and 2022 cropping seasons of the same genotypes (1.00 - 1.27) in sole and (0.50 - 1.02) in intercropping, it can be deduced that, only the genotypes Secow-1T, Nizwe, THIEY, Leona, Narocowpea-6, Gujaratcowpea-3, and Narocowpea-2 showed significant differences ($p < 0.05$) in grain yields (**Figure 6**). The least grain yields were recorded in the genotypes Nizwe and THIEY thought they have appreciable yields in sole cropping. They are therefore most suitable for sole cropping. Genotypes, Narocowpea-5, Secow-1T, Narocowpea-4, CK1-Padi tuya, Leona, CK2, Gujaratcowpea-3, and Aygenkwa are good candidates for maize cowpea intercropping systems. Cropping systems might impact grain yields and accounted for the variations in grain harvest. It was found that intercropping has a positive or negative influence on the yield potential of certain cowpea genotypes as described in [25]. In the 2021 and 2022 intercropping seasons, there were no significant differences ($p > 0.05$) in grain yield between the Narocowpea-5, Nizwe, Narocowpea-4, THIEY, CK1-Padi tuya, Narocowpea-6, CK2, Aygenkwa and Narocowpea-2 genotypes. However, in the sole and intercropping systems, these genotypes were subjected to the same screening procedure and produced very low yields, below 1.00 and 0.50 tons per hectare, respectively. They are therefore neither suitable for intercropping with maize nor for sole cropping. To help farmers, cowpea genotypes suitable for intercropping with cereals and tuber crops need to be screened and developed [26].

There was no significant difference ($p > 0.05$) in biomass yield of Secow-2W, IT-38956-1, Plantlobia-1, CK4-W2 and SAM genotypes in 2021 and 2022. Nevertheless, there were significant differences ($p < 0.05$) between the genotypes Narocowpea-3, Secow-4W, Secow-3B and Secow-5T in 2021 and 2022. The intercropping of cowpea and maize can reduce biomass yield, as this study shows, which is in line with [27].

The subsequent analysis of the 29 cowpea genotypes showed that some genotypes had biomass values between 1.00 and 2.55 t/ha in intercropping systems and between 1.00 and 1.85 t/ha in sole cropping systems (**Figure 7**). The genotypes KBC-9, KT-Benga, IT99K573-1-1, Narocowpea-5 and CK1-Padi tuya showed no significant difference ($p > 0.05$) in biomass yield in the sole cropping system in 2021 and 2022 (**Figure 7**). In contrast, the genotypes UAM14-126-L33, Apagbala, Narocowpea-4, Narocowpea-6 and Narocowpea-2 showed a remarkable variation in biomass yield between the sole cropping systems 2021 and 2022. The genotypes KBC-9, KT-Benga, Apagbala, IT99K573-1-1, Narocowpea-5 and CK1-Padi tuya did not differ significantly ($p > 0.05$) in biomass yield in the intercropping system in 2021 and 2022. But these genotypes; UAM14-126-L33, Narocowpea-4, Narocowpea-6, and Narocowpea-2 exhibited significant differences ($p < 0.05$) in biomass yield in the intercropping systems during the 2021 and 2022 seasons. The biomass yield of the genotypes KBC-9, KT-Benga and IT99K573-1-1 increased in both cropping years. They can therefore be considered ideal candidates for biomass production in intercropping systems. Thus, intercropping increases the biomass yields of these genotypes; these results are in agreement with [28]. It is interesting to note that the genotypes KBC-9, KT-Benga, UAM14-126-L33, Apagbala and IT99K573-1-1 achieved significant biomass and grain yields both in intercropping and sole cropping (**Figure 8(A)** and **Figure 8(B)**). They are good genotypes for both cropping systems. This study shows that different cropping systems, including cowpea in intercropping and sole cropping, have an effect on biomass yield. This is consistent with the results of Takim *et al.* [29].

5. Conclusions and Policy Recommendation

The genotypes in both cultivation systems show significant differences in the number of days to 50% flowering, the number of pods per plant, the number of days to 95% pod maturity and the grain and biomass yields. The days to 50% flowering, the days to 95% pod maturity and the grain and biomass yields of the genotypes are not always correlated with each other. The study provides valuable insights into the basic characteristics of certain cowpea genotypes, which could prove useful for future breeding initiatives. According to the results of the study, intercropping systems can be a sustainable way to maximize grain and biomass yields of certain cowpea genotypes. When maize and cowpea are grown together, the two crops compete more strongly with each other than when grown alone, which has an impact on grain and biomass yields. The comparative area, the land equivalent ratio of the genotypes, which was higher than one in the intercropping system, indicates the best possible use and exploitation of natural resources. The genetic variants of the crossbred genotypes can be used to improve one or more other traits that may be lacking before the crossbred cowpeas are released to farmers.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Ddungu, S.P., Ekere, W., Bisikwa, J., Kawooya, R., Kalule, D.O. and Biruma, M. (2015) Marketing and Market Integration of Cowpea. *Journal of Development and Agricultural Economics*, **7**, 1-11. https://doi.org/10.5897/jdae2014.0577

[2] Abate, T., Alene, A.D., Bergvinson, D., Shiferaw, B., Silim, S., Orr, A. and Asfaw, S. (2012) Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT): Nairobi, Kenya.

[3] Mumuni, A., Shaibu, S.S., Mohammed, H., Adams, M.M. and Stephen, K.A. (2016) Farmer Participatory Pest Management Evaluations and Variety Selection in Diagnostic Farmer Field Fora in Cowpea in Ghana. *African Journal of Agricultural Research*, **11**, 1765-1771. https://doi.org/10.5897/ajar2016.10887

[4] Timko, M.P. and Singh, B.B. (2008) Cowpea, a Multifunctional Legume. In: Moore, P.H. and Ming, R., Eds., *Genomics of Tropical Crop Plants*, Springer (New York), 227-258. https://doi.org/10.1007/978-0-387-71219-2_10

[5] Simion, T. (2018) Breeding cowpea *Vigna unguiculata* [L.,] Walp for Quality Traits. *Annals of Reviews and Research*, **3**, 555-609. https://doi.org/10.19080/ARR.2018.03.555609

[6] Egbadzor, K.F., Yeboah, M., Offei, S.K., Ofori, K. and Danquah, E.Y. (2013) Farmers' Key Production Constraints and Traits Desired in Cowpea in Ghana. *Journal of Agricultural Extension and Rural Development*, **5**, 14-20.

[7] Banik, P., Midya, A., Sarkar, B.K. and Ghose, S.S. (2006) Wheat and Chickpea Intercropping Systems in an Additive Series Experiment: Advantages and Weed Smothering. *European Journal of Agronomy*, **24**, 325-332. https://doi.org/10.1016/j.eja.2005.10.010

[8] Tsubo, M., Walker, S. and Ogindo, H.O. (2005) A Simulation Model of Cereal-Legume Intercropping Systems for Semi-Arid Regions. *Field Crops Research*, **93**, 23-33. https://doi.org/10.1016/j.fcr.2004.09.003

[9] Baumann, D.T. (2000) Intercropping Leeks to Suppress Weeds. *Weed Research*, **40**, Article 359.

[10] Szumigalski, A. and Van Acker, R. (2005) Weed Suppression and Crop Production in Annual Intercrops. *Weed Science*, **53**, 813-825. https://doi.org/10.1614/ws-05-014r.1

[11] Dahmardeh, M., Ghanbari, A., Syahsar, B.A. and Ramrodi, M. (2010) The Role of Intercropping Maize (*Zea mays* L.) and Cowpea (*Vigna unguiculata* L.) on Yield and Soil Chemical Properties. *African Journal of Agricultural Research*, **5**, 631-636.

[12] Takim, F.O. (2012) Advantages of Maize-Cowpea Intercropping over Sole Cropping through Competition Indices. *Journal of Agriculture and Biodiversity Research*, **1**, 53-59.

[13] Mucheru-Muna, M., Pypers, P., Mugendi, D., Kung'u, J., Mugwe, J., Merckx, R., *et al.* (2010) A Staggered Maize-Legume Intercrop Arrangement Robustly Increases Crop Yields and Economic Returns in the Highlands of Central Kenya. *Field Crops Research*, **115**, 132-139. https://doi.org/10.1016/j.fcr.2009.10.013

[14] Langyintuo, A.S., Lowenberg-DeBoer, J., Faye, M., Lambert, D., Ibro, G., Moussa, B.,

et al. (2003) Cowpea Supply and Demand in West and Central Africa. *Field Crops Research*, **82**, 215-231. https://doi.org/10.1016/s0378-4290(03)00039-x

[15] Bawayelaazaa Nyuor, A., Donkor, E., Aidoo, R., Saaka Buah, S., Naab, J., Nutsugah, S., *et al.* (2016) Economic Impacts of Climate Change on Cereal Production: Implications for Sustainable Agriculture in Northern Ghana. *Sustainability*, **8**, Article 724. https://doi.org/10.3390/su8080724

[16] Abdul Rahman, N., Larbi, A., Kotu, B., Asante, M.O., Akakpo, D.B., Mellon-Bedi, S., *et al.* (2021) Maize-Legume Strip Cropping Effect on Productivity, Income, and Income Risk of Farmers in Northern Ghana. *Agronomy Journal*, **113**, 1574-1585. https://doi.org/10.1002/agj2.20536

[17] Dapaah, H.K., Asafu-Agyei, J.N., Ennin, S.A. and Yamoah, C. (2003) Yield Stability of Cassava, Maize, Soya Bean and Cowpea Intercrops. *The Journal of Agricultural Science*, **140**, 73-82. https://doi.org/10.1017/s0021859602002770

[18] Naab, J.B., Chimphango, S.M.B. and Dakora, F.D. (2009) N2 Fixation in Cowpea Plants Grown in Farmers' Fields in the Upper West Region of Ghana, Measured Using15n Natural Abundance. *Symbiosis*, **48**, 37-46. https://doi.org/10.1007/bf03179983

[19] Alidu, M.S. (2019) Evaluation of Planting Dates on Growth and Yield of Three Cowpea [*Vigna unguiculata* (L) Walp.] Genotypes in Northern Ghana. *Advances in Research*, **18**, 1-14. https://doi.org/10.9734/air/2019/v18i430097

[20] Mead, R. and Willey, R.W. (1980) The Concept of a 'Land Equivalent Ratio' and Advantages in Yields from Intercropping. *Experimental Agriculture*, **16**, 217-228. https://doi.org/10.1017/s0014479700010978

[21] Owusu, E.Y., Akromah, R., Denwar, N.N., Adjebeng-Danquah, J., Kusi, F. and Haruna, M. (2018) Inheritance of Early Maturity in Some Cowpea (*Vigna unguiculata* (L.) Walp.) Genotypes under Rain Fed Conditions in Northern Ghana. *Advances in Agriculture*, **2018**, 1-10. https://doi.org/10.1155/2018/8930259

[22] Song, Y.H., Ito, S. and Imaizumi, T. (2013) Flowering Time Regulation: Photoperiod and Temperature-Sensing in Leaves. *Trends in Plant Science*, **18**, 575-583. https://doi.org/10.1016/j.tplants.2013.05.003

[23] Hadi, H., Golezani, K.G., Khoei, F.R., Valizadeh, M. and Shakiba, M.R. (2006) Response of Common Bean (*Phaseolus vulgaris* L.) to Different Levels of Shade. *Journal of Agronomy*, **5**, 595-599. https://doi.org/10.3923/ja.2006.595.599

[24] Singh, B.B., Olufajo, O.O., Ishiyaku, M.F., Adeleke, R.A., Ajeigbe, H.A. and Mohammed, S.G. (2007) Registration of 'NGVU - 05 - 24' Cowpea. *Journal of Plant Registrations*, **1**, 48-49. https://doi.org/10.3198/jpr2006.03.0138crc

[25] Nelson, S.C. and Robichaux, R.H. (1997) Identifying Plant Architectural Traits Associated with Yield under Intercropping: Implications of Genotype-Cropping System Interactions. *Plant Breeding*, **116**, 163-170. https://doi.org/10.1111/j.1439-0523.1997.tb02172.x

[26] Olufajo, O.O. and Singh, B.B. (2002) Advances in Cowpea Cropping Systems. *Challenges and Opportunities for Enhancing Sustainable Cowpea Production*, International Institute of Tropical Agriculture, Ibadan, 267.

[27] Padi, F.K. (2007) Genotype×Environment Interaction and Yield Stability in a Cowpea-Based Cropping System. *Euphytica*, **158**, 11-25. https://doi.org/10.1007/s10681-007-9420-8

[28] Singh, M., Singh, A., Singh, S., Tripathi, R.S., Singh, A.K. and Patra, D.D. (2010) Cowpea (*Vigna unguiculata* L. Walp.) as a Green Manure to Improve the Productivity of

a Menthol Mint (*Mentha arvensis* L.) Intercropping System. *Industrial Crops and Products*, **31**, 289-293. https://doi.org/10.1016/j.indcrop.2009.11.004

[29] Takim, F.O. and Fadayomi, O. (2010) Influence of Tillage and Cropping Systems on Field Emergence, Growth of Weeds and Yield of Maize (‘*Zea mays*’ L.) and Cowpea (‘*Vigna unguiculata*’ L.). *Australian Journal of Agricultural Engineering*, **1**, 141–148.