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Growth, Development and Yield of Component Crops in a Maize-Cowpea Intercrop System in the Sudan Savannah Zone in Ghana

Listowell Aditwin Akologo[1], Harrison Kwame Dapaah[2], Margaret Esi Essifie[2], Julius Yirzagla[2], Emmanuel Aziiba Asibi[3]

[1]Gbewaa College of Education, Pusiga, Ghana
[2]Mampong Campus, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong, Ghana
[3]CSIR-SARI, Nyankapla, Ghana
Email: aditwinlisto@gmail.com, hkdapaah@aamsted.edu.gh, aziiba4uson@yahoo.com

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Abstract

A maize-cowpea intercrop multi-location study was conducted at the experimental fields of the Council for Scientific and Industrial Research-Savannah Agricultural Research Institute (CSIR-SARI) at Manga, Binduri District and at the Presbyterian Agricultural Station (PAS) at Garu, in the Garu District from July to October 2021 and 2022 cropping seasons. The objective of the study was to determine the influence of a maize-cowpea intercrop system on the growth, development and yield of maize and cowpea in a multi-location trial as a climate-smart agriculture innovation to increase crop productivity in the Sudan Savannah Agro-Ecological zone in Ghana. The study was a 3 × 3 factorial experiment laid out in a Randomized Complete Block Design (RCBD) with four replications. The factors studied were (A) Row arrangements: [(i)1 row maize altenating with 1 row cowpea (1M:1C), (ii) 2 rows maize altenating with 2 rows cowpea (2M:2C) and (iii) 3 rows maize alternating with 3 rows cowpea (3M:3C)] and (B) Relative times of planting: [(i)Simultaneous planting of maize and cowpea (SIM), (ii) maize planted 2 weeks before cowpea (M2WBC) and cowpea planted 2 weeks before maize (C2WBM)]. Sole maize and sole cowpea crops were included in the treatments. The intercropping systems largely enhanced phenological and growth variables of the component crops. Generally, the yields of both maize and cowpea were significantly higher than the yields of sole maize and cowpea at both Garu and Manga in 2021 and 2022. The simultaneous planting at 2M:2C produced the highest maize yield of 13.33 t/ha while the lowest grain yield (1.40 t/ha) of maize came from Manga in 2021. However, the highest cowpea yield was obtained when cowpea was planted 2 WBM at 1M:1C (3.79 t/ha). It is recommended that farmers with priority for maize yields could adopt planting the two crops simultaneously at 2M:2C row arrangement for maximum maize yields and farmers with priority for cowpea yields could adopt planting cowpea 2 weeks before maize at 1M:1C to maximize cowpea yields.

Subject Areas

Agricultural Science

Keywords

Agro-Ecological, Ecosystem Services, Phenological Development, Component Crops

1. Background

Maize (*Zea mays* L.) is a major staple cereal crop that provides energy for millions of the global population, particularly in Africa and Asia, where it is a major contributor to global food security [1]. It is a major cereal crop grown in Ghana, contributing to about 50% - 60% human and animal feed and thrives well in all the agro-ecological zones in the country. It is high-yielding, hence contributes largely to food security in poor communities to ameliorate the impact of climate change on crop productivity and production [2]. The crop is compatible with leguminous crops in both tropical and temperate regions and provides relatively high productivity per unit area, adaptable to major agro-ecologies, and easily used in traditional food preparations. It is a food security crop with short maturation that is used to reduce hunger, particularly in the Savannah Regions of Ghana. It also supports biodiversity conservation and improves soil health for agricultural activities [3] [4].

Cowpea (*Vigna unguiculata*) is a shade-tolerant leguminous crop that is compatible in intercropping systems with cereal crops such as maize (*Zea mays* L.), millet (*Pennisetum glaucum* L.) and sorghum (*Sorghum bicolor* L. Moench) [4]. Apart from its high protein content, cowpea contains essential food nutrients such as fat and oils and hence its consumption is recommended for the reduction of household malnutrition in poorer communities. It is also consumed as a leafy vegetable in many parts of the world.

Maize and cowpea production is currently challenged by poor yields due to climate change, poor agricultural practices and unfavourable climatic conditions, necessitating the need for resilient or regenerative agricultural practices such as intercropping. To increase crop yields, farmers must innovate through ecological intensification to boost production and increase resilience to weather extremes. Intercropping can strengthen and stabilize agro-ecosystems under climate change by improving resource use efficiency, enhancing soil water holding capacity and increasing the diversity [5] [6]. It involves both conservation and sustainable agricultural practices for increased crop resilience and yields.

There are declining crop yields of maize and other arable crops such as cowpea in the Guinea and Sudan Savannah Ecological zones in Ghana, largely due to inconsistent rainfall patterns and ever increasing temperatures. Smallholder farmers in the Savannah areas in Ghana, practise mostly cereal-legume intercropping to mitigate risks of crop failure in the over-dominant mono-cropping systems [4]. The phenomenon of depleting factors of production requires the use of improved farming systems, innovative production technologies, climate-smart agricultural techniques and improved planting materials such as seeds to ensure increased crop productivity, resilience and sustainability. The prevailing climatic conditions and the purpose of production in any given area determine the cropping systems adopted.

To ameliorate the impact of declining soil fertility and impact of climate change, intercropping can be adopted to increase productivity and improve farmers' livelihood due to increased incomes from sale of produce. According to [7] [8] increased agricultural productivity and incomes can reduce rural poverty among vulnerable people.

The objective of the study was therefore to examine the influence of a maize-cowpea intercrop system on the growth, development and yield of component crops in the Sudan Savannah Agro-Ecological zone of Ghana.

2. Materials and Methods

2.1. Experimental Site

The study was conducted in the Sudan Savannah Ecological Zone in the Upper East Region in Ghana, at CSIR-SARI station at Manga and the Presbyterian Agricultural Station (PAS), at Garu. The study was carried out at both locations from July to October, 2021 for the first year and from July to October, 2022 for the second year. Binduri District is located approximately between latitudes 11˚11′S and 10˚40′N and longitudes 0˚18′W and 0˚6′E in the North-Eastern corner of the Upper East Region. The second location, PAS, Garu District, is located in the north-eastern part of the Upper East Region between Latitude 10˚1′N and Longitude 0˚1′W.

2.2. Soil Analysis and Climatic Conditions

Initial soil (0 cm - 30 cm depth) at Garu indicated soil chemical properties of pH 5.7. It contained major nutrients of N (0.02 mg/kg), P (1.5 mg/kg) and K (22.2 mg/kg). The minor nutrients were Ca^{2+} (0.8 cmol/kg) and Mg^{2+} (0.7 cmol/kg) with OC (0.5). The loamy sand contained sand (80.2%), clay (9.6%) and silt (10.2%) (**Table 1**). Similarly, initial soil analysis at Manga indicated soil chemical properties of pH 5.6. It also contained major nutrients of N (0.03 mg/kg), P (1.4 mg/kg) and K (24 mg/kg). The minor nutrients possessed were Ca^{2+} (0.9 cmol/kg) and Mg^{2+} (0.7 cmol/kg) with OC (0.5 mg/kg). The loamy sand contained sand (83.9%), clay (6.4%) and silt (9.7%) (**Table 2**).

Generally, the initial soil analysis for both Garu and Manga showed the soils were slightly acidic and that the nutrient level were low phosphorus, nitrogen and manganese. However, the initial soil analysis indicated that soil from both locations had medium organic carbon and potassium (CSIR-SARI, 2007). The soil belongs to the Varempare Series, which are mainly sandy loams associated with hornblende and granites, while the PAS soils belong to the Tafali Series, which is also suitable for the cultivation legumes, cereals and vegetables. The climate of both locations is characterised by a unimodal rainy season from May /June to October and a dry harmattan season from November to April. The average amount of rainfall during the period is between 800 - 860 mm per annum. The vegetation is mainly the Sudan Savannah Ecology.

2.3. Experimental Design and Treatments

The experimental design used for the study was a 3 × 3 factorial arranged in a Randomized Complete Block Design (RCBD) with 4 replications. The treatments consisted (A) row arrangements [(i) 1 row maize altenating with 1 row cowpea (1M:1C), (ii) 2 rows maize altenating with 2 rows cowpea (2M:2C) and (iii) 3 rows maize altenating with 3 rows cowpea (3M:3C)] and (B) relative times of planting [(i) Simultaneous planting of maize and cowpea (SIM), (ii) maize planted 2 weeks before cowpea (M2WBC) and (iii) cowpea planted 2 weeks before maize (C2WBM)]. Sole maize and sole cowpea crops were added for comparison, bringing the total number of treatments to eleven (11). Maize seeds were planted at 0.75 m × 0.4 m, while the cowpea seeds were planted 0.75 m × 0.2 m. Each plot consisted of 4 sets of the intercrops for the 1M:1C and 3 sets of intercrops for the 2M:2C and 3M:3C. The central two sets of the intercrops for 1M:1C and 1 set of intercrops for 2M:2C and 3M:3C served as the harvestable areas for the final yield and yield components assessment. The sole maize and cowpea plots were planted with 6 rows per plot. Row length was 5 m. The 2 central rows of the sole maize and cowpea served as harvestable rows. Improved medium-maturing maize variety (Wangdataa) and improved medium-maturing cowpea variety (Wangkae) were sourced from Manga.

2.4. Crop Management and Cultural Practices

The experimental fields at both locations were ploughed with a tractor and an animal-drawn mould board plough used in ridging. Ridges formed measured 0.75 m apart. Planting of maize and cowpea was done with hoes. The crops were planted 3 seeds per hill and later thinned to two plants per hill when plants were established. The sole maize and cowpea were planted when component crops were planted simultaneously. Manual weeding was done when necessary, till component crops were harvested. Basal application of Nitrogen Phosphorus Potassium (NPK) was applied to the maize crop at the rate of 68 kg N, 38 kg P_2O_5 and 38 K_2O at 14 DAP and top-dressed with urea at 65.2 kg ha^{-1} at 50 DAP.

Inoxacarb (30 g/L and Acetamiprid (16 g/L), a systemic insecticide against armyworm and a wide spectrum of pests on maize and vegetables were used. The

Viper 46 EC (0.4 L/Acre), equivalent to 40 mL/15L of water and (Inoxacarb, 30 g/L and Acetamiprid, 16 g/L) were sprayed. The spraying was carried out on both maize and cowpea plots across both locations and seasons. Generally, high farm hygiene was maintained to ensure maximum productivity.

3. Results and Discussion

3.1. Growth Variables of Maize

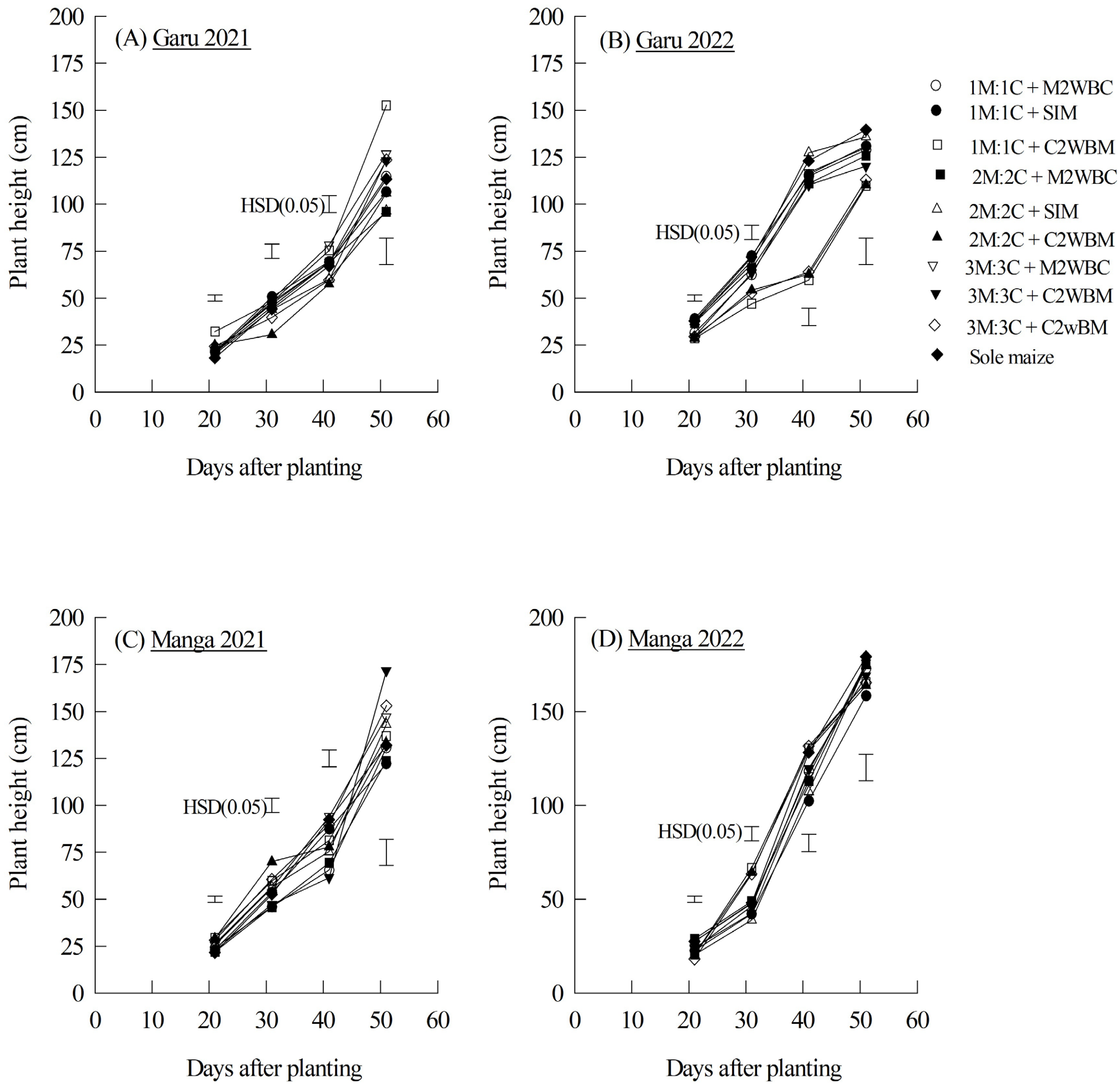

Figure 1. Plant height of maize as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

Generally, plant height, total dry matter, leave area index, photosynthetically active radiation and chlorophyll content were significantly ($p < 0.05$) affected by row arrangement, relative times of planting, location and year with significant interactions. Positive interaction of the simultaneously planted component crops also promoted the effective utilization of growth resources that affected its growth and development. According to [9], increased plant height provides more green area for increased photosynthetic activities, absorption and translocation of assimilates needed for effective grain filling to obtain higher yields. According to [10], maize is very sensitive to the spatial arrangement of the intercropping of component crops. The row arrangement automatically spaced the maize plants, hence less competition for radiation was experienced resulting in homogeneous maize height at early stages [11]. Significant differences and interactions were recorded due to available radiation [12] [13]. Maize-cowpea intercropping influenced the maize photosynthetic rate and chlorophyll accumulation due to the complementarity effect of ecosystem services from cowpea to maize. Photosynthetic variables indicated high performance indicating that intercropping can significantly improve the photosynthetic rate and chlorophyll accumulation of maize plants [3] [14]-[16]. Dry matter (DM) accumulation and its allocation to kernels are key factors that determine the final maize grain yield [17] (**Figures 1-5**).

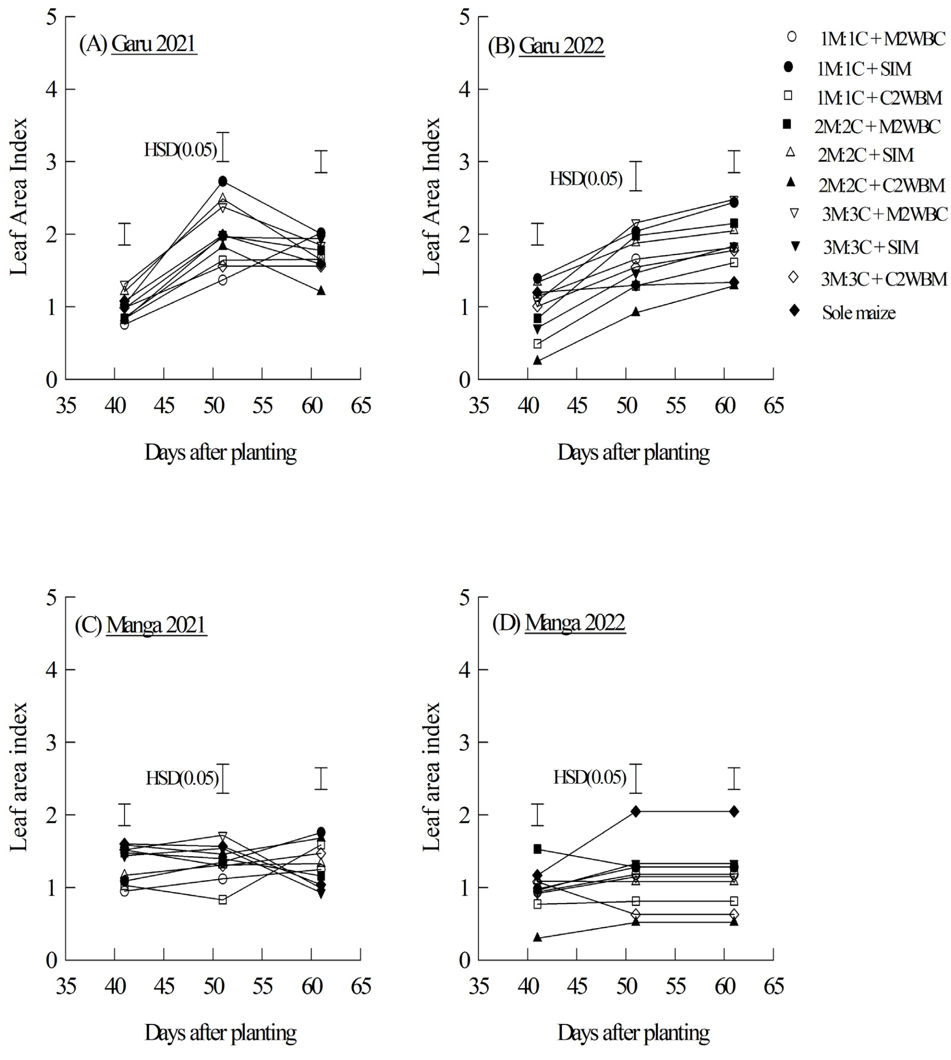

Figure 2. Leaf area index of maize as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

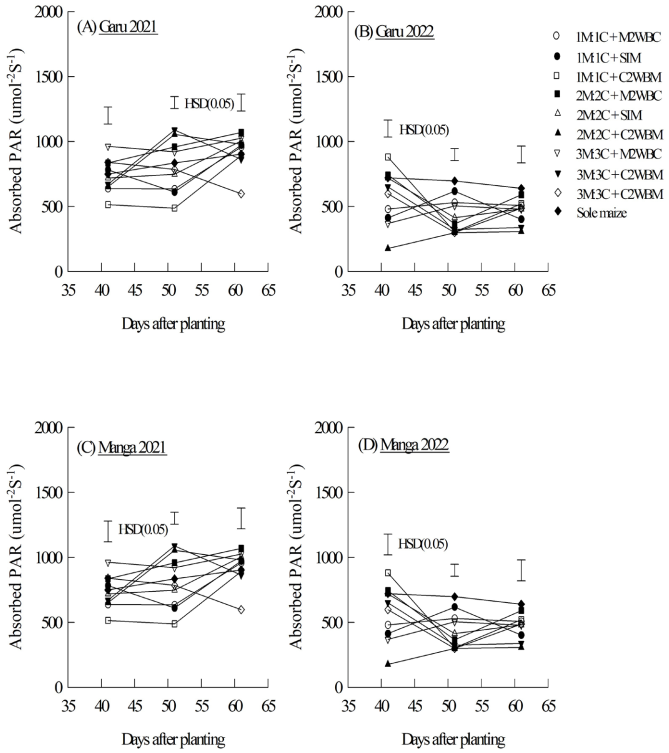

Figure 3. Absorbed Photosynthetically Active Radiation by maize as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

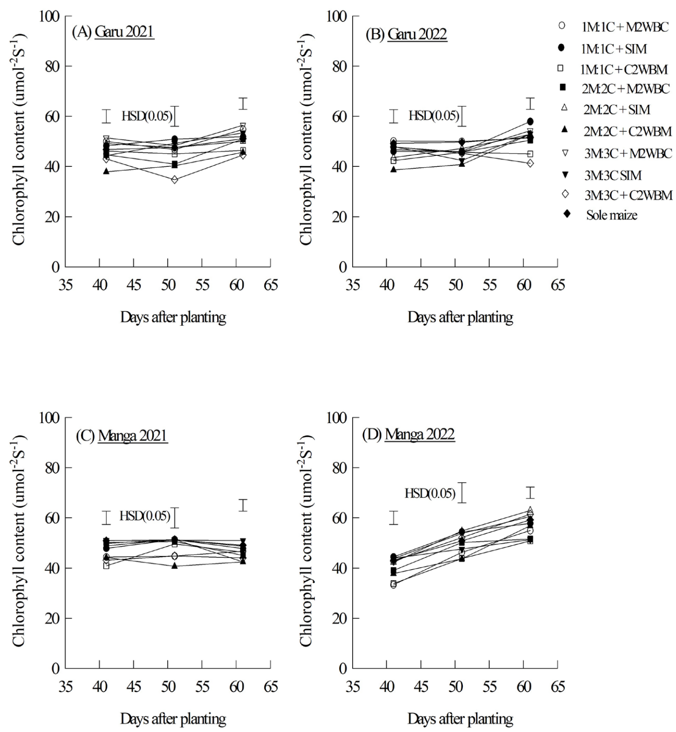

Figure 4. Chlorophyll content of maize leaves as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

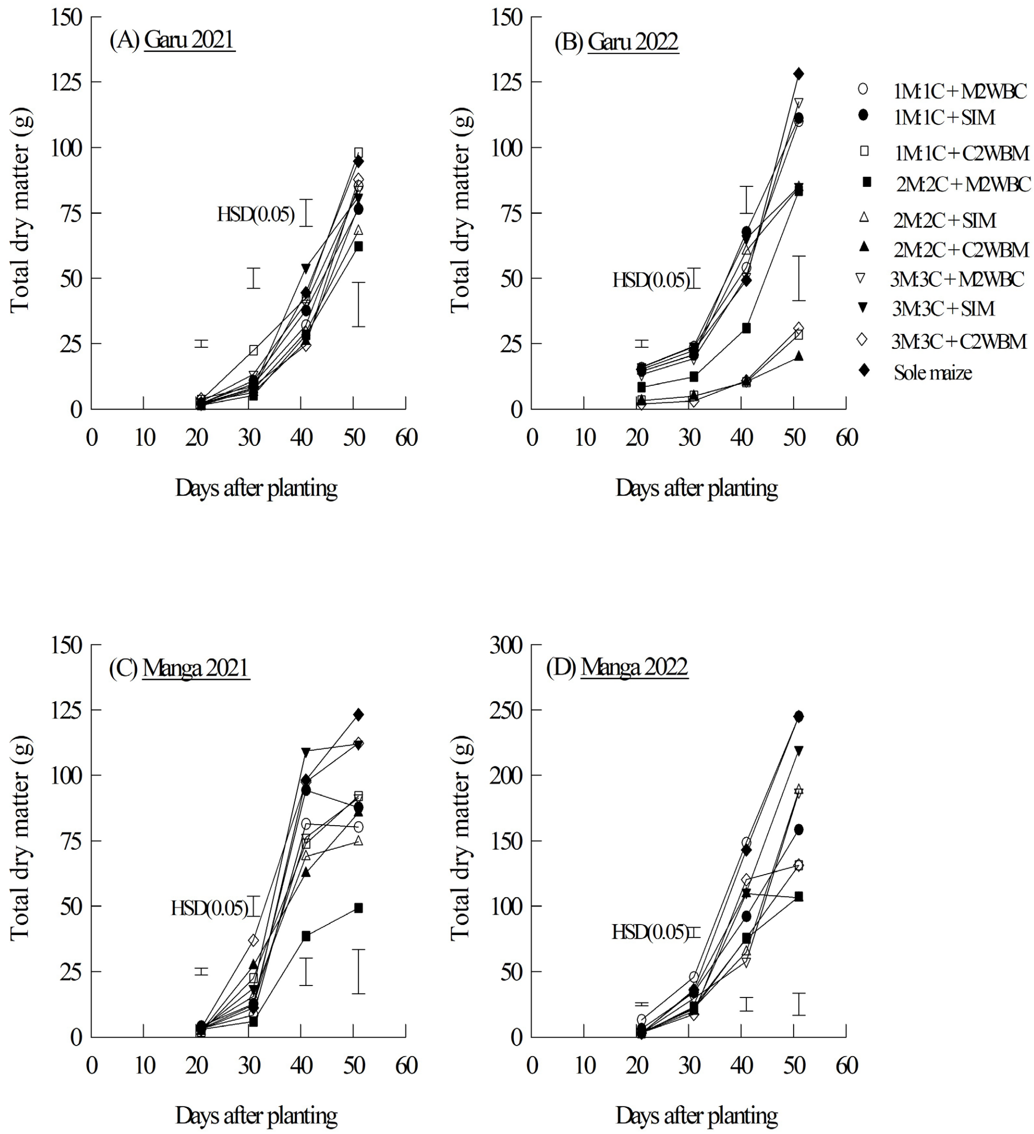

Figure 5. Total Dry Matter of maize as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing.

3.2. Development of Maize

The combined analysis of maize across the two locations and years indicated that relative times of planting (RTP) and row arrangement (RA) significantly influenced the phenological development of maize. A higher plant establishment, early tasseling and silking are determined good maize yield. These phenological parameters were obtained due to favourable environmental conditions. However, maize tasselling significantly differed ($p < 0.05$) between the seasons in the first year with maize tasseling earlier (52 days) than the second season (53 days). This was due to the different environmental conditions experienced at both experimental sites. Favourable climatic conditions experienced at both locations during the study influenced phenological development [13] [18] [19] (**Table 1** and **Table 2**).

Table 1. Days to 50% tasselling of maize as affected by row arrangement and relative times of planting at Garu and Manga in 2021 and 2022.

Cropping systems		Days to 50% Tasselling					
		Garu			Manga		
Row arrangement (RA)	Relative times of planting (RTP)	2021	2022	Mean	2021	2022	Mean
1M:1C†	M2WBC#	53	55	54	53	50	52
	SIM	51	55	53	51	55	53
	C2WBM	46	48	47	52	54	53
2M:2C	M2WBC	54	55	55	54	53	54
	SIM	51	55	53	51	53	52
	C2WBM	46	48	47	51	54	53
3M:3C	M2WBC	50	55	53	50	50	50
	SIM	52	55	54	51	55	53
	C2WBM	46	49	48	51	53	52
Mean		50	53		52	53	
Sole maize		50	55	53	50	53	53
RA		HSD = NS p = 0.5513			HSD = NS p = 0.4766		
RTP		HSD = 1.058 p < 0.0001			HSD = NS p = 0.4143		
Year		HSD = 0.718 p < 0.0001			HSD = 1.191 p = 0.0207		
<u>Interactions</u>							
RA × RTP		HSD = NS p = 0.1405			HSD = NS p = 0.0885		
RA × Y		HSD = NS p = 0.2623			HSD = NS p = 0.7260		
RTP × Y		HSD = NS p = 0.1074			HSD = 2.480 p = 0.0048		
RA × RTP × Y		HSD = NS p = 0.1417			HSD = NS p = 0.7644		

Note: †: 1M:1C = 1 row maize alternating with 1 row cowpea; 2M:2C = 2 rows maize alternating with 2 rows cowpea; 3M:3C = 3 rows maize alternating with 3 rows cowpea; #: M2WBC = Maize planted 2 weeks before cowpea; C2WBM = Cowpea planted 2 weeks before maize.

Table 2. Days to 50% silking of maize as affected by row arrangement and relative times of planting at Garu and Manga in 2021 and 2022.

Cropping systems		Days to 50% Silking					
		Garu			Manga		
Row arrangement (RA)	Relative times of planting (RTP)	2021	2022	Mean	2021	2022	Mean
1M:1C†	M2WBC#	54	60	57	54	54	54
	SIM	55	60	57	54	60	57
	C2WBM	55	53	54	55	59	57
2M:2C	M2WBC	56	60	58	56	57	57
	SIM	54	60	57	52	60	56
	C2WBM	56	54	55	56	59	58
3M:3C	M2WBC	54	60	57	53	56	55
	SIM	54	60	57	55	60	58
	C2WBM	57	53	55	57	59	58
Mean		55	58		55	58	
Sole maize		55	60	58	54	59	57
RA		HSD = NS $p = 0.7056$			HSD = NS $p = 0.7157$		
RTP		HSD = 1.562 $p < 0.0001$			HSD = 1.996 $p = 0.0194$		
Year		HSD = 1.061 $p < 0.0001$			HSD = 1.356 $p < 0.0001$		
<u>Interactions</u>							
RA × RTP		HSD = NS $p = 0.7893$			HSD = NS $p = 0.4061$		
RA × Y		HSD = NS $p = 0.7785$			HSD = NS $p = 0.8841$		
RTP × Y		HSD = 2.209 $p < 0.0001$			HSD = 2.823 $p = 0.0124$		
RA × RTP × Y		HSD = NS $p = 0.6014$			HSD = NS $p = 0.6337$		

Note: †: 1M:1C = 1 row maize alternating with 1 row cowpea; 2M:2C = 2 rows maize alternating with 2 rows cowpea; 3M:3C = 3 rows maize alternating with 3 rows cowpea; #: M2WBC = Maize planted 2 weeks before cowpea; C2WBM = Cowpea planted 2 weeks before maize.

3.3. Total Grain Yield of Maize

There were significant effects and interactions of RA, RTP and Year on total grain yield of maize for both locations and seasons. Maize planted 2 weeks before cowpea and maize planted simultaneously produced the highest grain yield than yields from maize planted 2 weeks after cowpea for the two seasons and experimental sites. The intercrop plots generally produced maize yields that were higher than the sole crops indicating higher crop productivity and efficient land use cropping system. The average total yield per hectare of 8.18 t/ha for Garu and 5.52 t/ha for Manga is far above the average maize in the Sudan ecological zone of 3.5 t/ha. The dominant performance of maize for both locations and seasons were maize planted 2 weeks before cowpea and maize planted simultaneously. This was due to early establishment, high tasselling, silking and other growth parameters obtained that gave them competitive advantage over the late crops. There was also effective use of growth resources to promote phenological and vegetative growth and finally yield and yield components of component crops. Similarly, planting maize 2 weeks before cowpea gave the maize a head start before the late crop. The higher maize grain yield obtained from the study in both locations and years could also be attributed to adequate and stable distribution of rainfall during the vegetative, tasselling, silking and grain filling stages of the maize plant because these are the growth stages that require adequate water for vigorous plant growth and efficient grain filling as reported by [19]-[21]. Maize yields obtained suggest that the overall productivity of the intercrop system was superior to the sole crop. Earlier studies confirm these findings [2] [8] (**Table 3**).

Table 3. Total Grain Yield of Maize as affected by row arrangement and relative times of planting at Garu and Manga in 2021 and 2022.

Cropping systems		Total Maize Grain Yield (t/ha)					
		Garu			Manga		
Row arrangement (RA)	Relative times of planting (RTP)	2021	2022	Mean	2021	2022	Mean
1M:1C†	M2WBC#	8.02	6.63	7.32	5.60	6.60	6.10
	SIM	8.82	8.93	8.88	6.80	5.27	6.03
	C2WBM	5.07	6.60	5.83	2.67	3.67	3.17
2M:2C	M2WBC	6.87	8.93	7.90	6.40	8.27	7.33
	SIM	7.67	13.33	10.50	7.40	6.33	6.87
	C2WBM	5.07	6.67	5.87	2.87	4.87	3.87
3M:3C	M2WBC	5.77	7.90	6.83	5.70	6.70	6.20
	SIM	6.37	8.22	7.30	3.64	4.53	4.09
	C2WBM	3.60	6.35	4.97	1.40	3.47	2.43
Mean		6.36	8.18		4.72	5.52	
Sole maize		7.27	12.80	10.04	6.67	7.33	7.00
RA		HSD = 1264.3 $p = 0.0021$			HSD = 1375.8 $p = 0.0026$		

Continued

RTP	HSD = 0.5836 p < 0.0001	HSD = 1375.8 p < 0. 0001
Year	HSD = 858.49 p = 0.0003	HSD = 934.18 p < 0. 0001
Interactions		
RA × RTP	HSD = NS p = 0.6344	HSD = NS p = 0.3326
RA × Y	HSD = NS p = 0.4680	HSD = NS p = 0.7535
RTP × Y	HSD = NS p = 0.4766	HSD = 162.7 p = 0.0035
RA × RTP × Y	HSD = NS p = 0.6729	HSD = NS p = 0.4403

Note: †: 1M:1C = 1 row maize alternating with 1 row cowpea; 2M:2C = 2 rows maize alternating with 2 rows cowpea; 3M:3C = 3 rows maize alternating with 3 rows cowpea; #: M2WBC = Maize planted 2 weeks before cowpea; C2WBM = Cowpea planted 2 weeks before.

3.4. Growth Variables of Cowpea

Plant height of cowpea was significantly affected by row arrangement and relative times of planting at Garu and Manga in the 2021 and 2022 growing seasons. The intercrop system had no influence on plant height until plants attained 41 DAP where plant height was influenced largely, leading to significant variations among RA, RTP and Year. Plant height is genetically inclined than treatment combinations [22] [23]; however, creating a favourable environment can enhance the performance and growth variables such as plant height due to genetic × environment interaction. Cowpea planted simultaneously with maize and sole cowpea produced the tallest plants from 41 DAP onwards throughout the data sampling period due to early establishment, as they were planted at the same time, and the advantage of a head start over the cowpea planted late. Cowpea planted simultaneously grew taller than all the other treatments due to the benefit of ecosystem services from maize and minimal competition. Cowpea height started slowly and increased steadily to a height of 35 cm for the sole cowpea. This finding is in line with [4]. Taller cowpea plants have their pods above the ground, preventing pod soil contact at maturity, thus reducing post-harvest yield losses. Pods hanging above the ground help in effective harvesting to reduce post-harvest losses and contaminated cowpea grain. Total dry matter of cowpea recorded significant differences for both Garu and Manga in both 2021 and 2022 cropping seasons. Total dry matter accumulation indicated that cowpea planted 2 weeks before maize and sole cowpea grew vigorously and accumulated more total dry matter than those planted simultaneously and those planted 2 weeks after maize throughout the experimental period. The dominance of cowpea planted 2 weeks before maize and sole cowpea was due to early planting, the head start advantage, coupled with minimal competition for growth resources. The cowpea that were grown simultaneously and those planted after maize faced negative intra and inter competition from maize. This clearly indicates that the maize-cowpea intercrop productivity and stability study had a high impact on the amount of dry matter accumulated, as large biomass would normally produce high total dry matter [22]. Absorbed photosynthetically active radiation did not show any significant differences at 41 and 51 DAP of cowpea, but showed significant differences at 61 DAP for both Garu and Manga in both 2021 and 2022 cropping seasons. The initial absorbed photosynthetically active radiation was similar at 41 DAP, declined at 51 DAP, but increased at 61 DAP when cowpea plants were approaching physiological maturity at Garu in 2021 and 2022. Absorbed Photosynthetically Active Radiation by cowpea at manga in 2022 was more diverse with 3M:3C+M2WBC and 3M:3C+SIM producing higher Absorbed Photosynthetically Active Radiation than all the other treatment combinations. This could be attributed to the wide leave architecture of the 3M:3C row arrangements [10] and the architecture of the row arrangement, coupled with planting both component crops simultaneously. Absorbed photosynthetically active radiation measurement is very important to evaluate agricultural land use efficiency and crop productivity. Efficiently absorbed photosynthetically active radiation is a prerequisite for productive farmland use measurement. Photosynthesis rate can be measured using absorbed photosynthetically active radiation measurement to quantify its contribution to total crop yield [13]. Absorbed photosynthetically active radiation is a determinant of crop yield. After podding, the pods and the developing kernels become sinks and therefore need a lot of assimilates or photosynthates from the sources for proper kernel development and maturity. Chlorophyll content of cowpea registered significant differences at 41 and 51 DAP but showed no significant differences at 61 DAP for both Garu and Manga in both 2021 and 2022. Production of chlorophyll was largely homogeneous for cowpea at both locations and seasons. The differences that occurred at the initial stages of growth could be attributed to the available radiation with less shade from the maize from 41 - 51 DAP. The level of chlorophyll content in cowpea is attributed to differences in treatment combinations and environmental variables [10] [13]. This was also supported by [13] Leaf area index (LAI) of cowpea varieties is influenced by the plant architecture, spreading or prostrate, erect or semi-erect leave area index of cowpea did not record any significant differences at 41, 51, and 61 DAS for both Garu and Manga in both 2021 and 2022 cropping seasons. About 72% of plots recorded leaf area index more than 1, thus enhancing flowering, podding and increased yield of cowpea. According to [20] [21], a leaf area index between 1 and 2 m^2 is required after flowering to obtain optimum yield of cowpea (**Figures 3-10**).

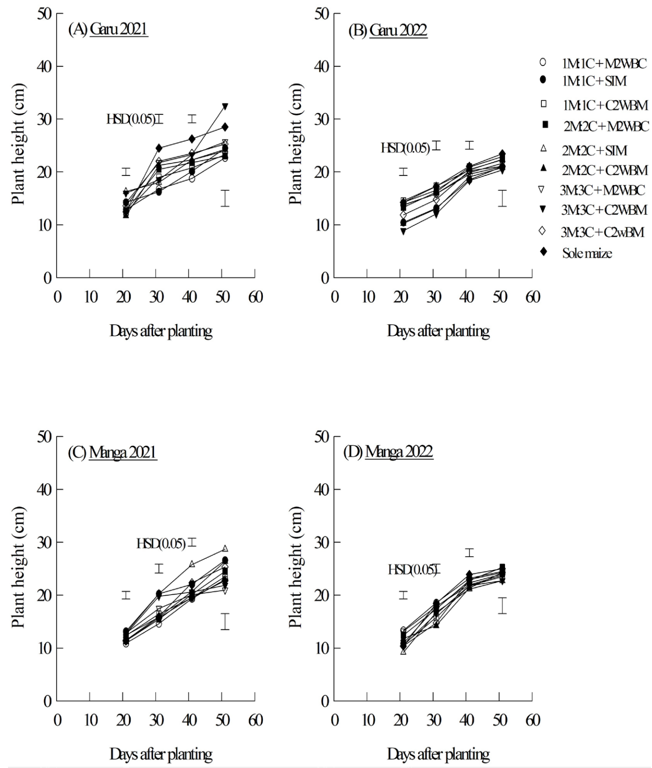

Figure 6. Plant height of cowpea as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

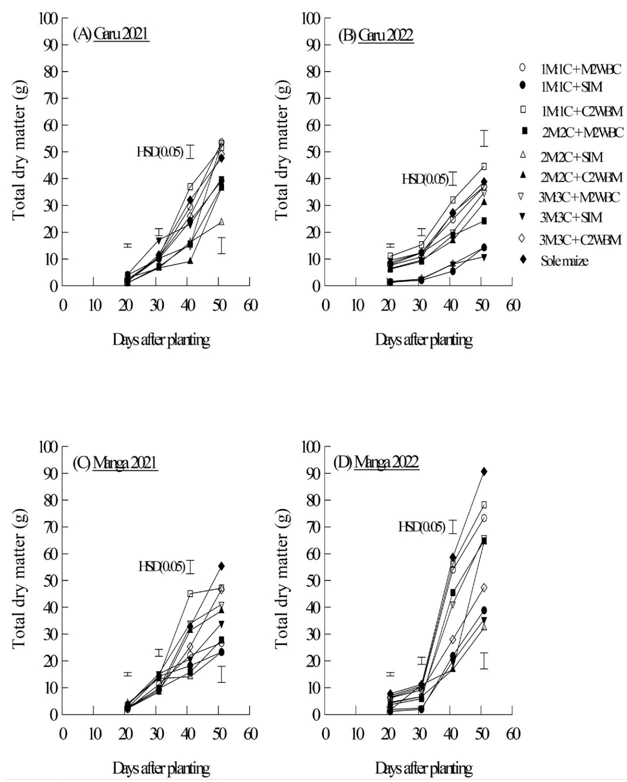

Figure 7. Total Dry Matter of cowpea as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

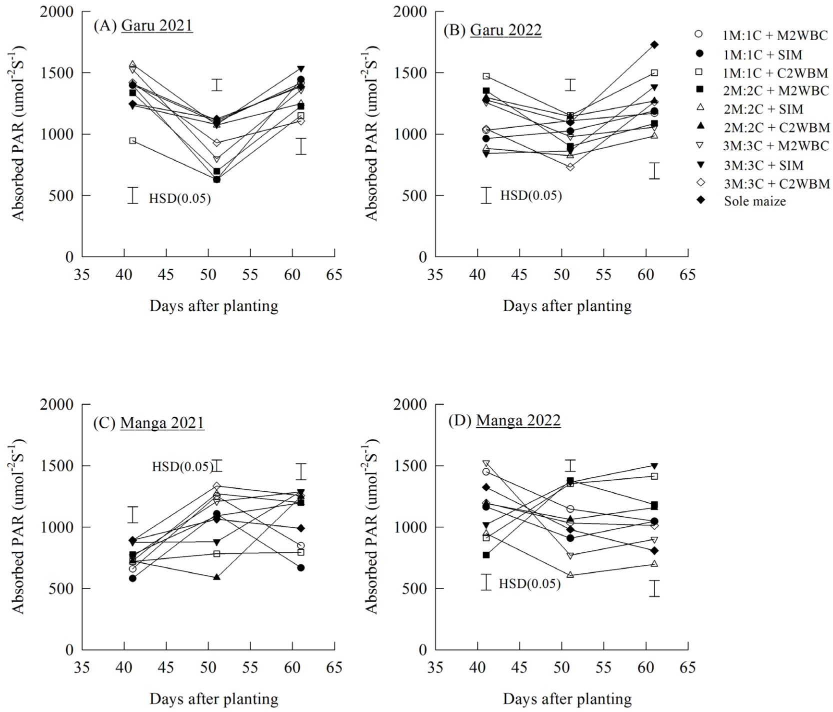

Figure 8. Absorbed Photosynthetically Active Radiation by cowpea as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

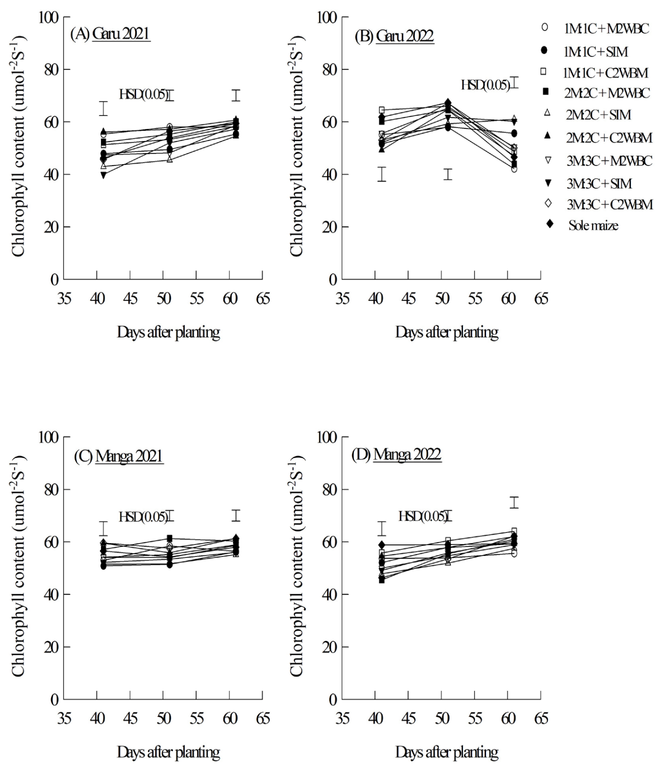

Figure 9. Chlorophyll content of cowpea leaves as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

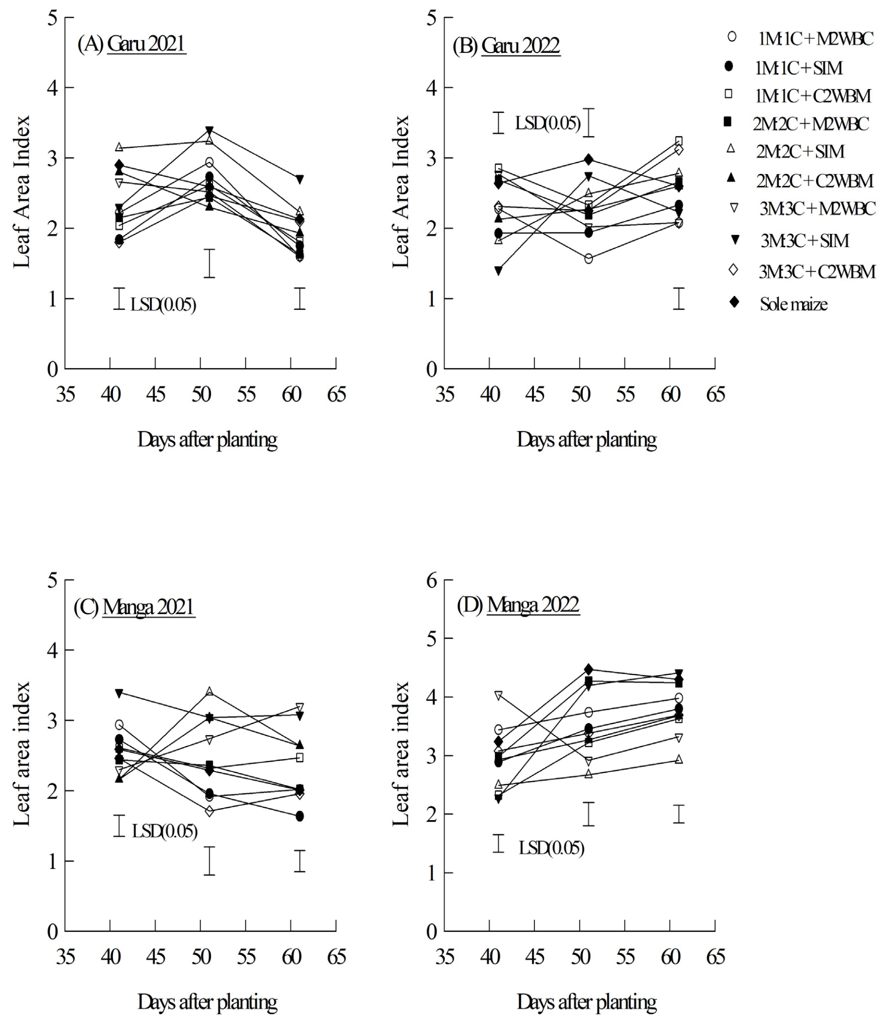

Figure 10. Leaf area index of cowpea as affected by row arrangement and relative times of planting in a maize + cowpea intercrop at Garu and Manga in 2021 and 2022 growing seasons.

3.5. Phenological Development of Cowpea

Percentage plant establishment at both experimental sites recorded an average of 97% for Garu and 96% for Manga during the experimental period. At 38 DAP, cowpea flowered and at 43 DAP 50% podding was archived. Early flowering normally enhances crop yield. Conditions that enhanced the phenological development during the study included adequate rainfall, temperature and day length. Plant establishment registered significant differences and interaction for Year and RTP. According to [23], temperature, water availability, light quality, photoperiod, altitude, and mineral nutrition determine effective and adequate percentage plant establishment. Days to 50% flowering of cowpea were significantly affected by RTP and RTP × Y interaction at both locations and seasons. Early flowering at 38 DAP at Garu was enhanced by the adequate rainfall experienced throughout the study period [22] [23]. This explains why row arrangement and relative times of planting had limited interactions and variations for days to 50% flowering of cowpea. There was no significant effect of RA on days to 50% to podding of cowpea, but there were significant and interaction effects of RTP and Year on days to 50% to podding for both seasons at Garu and Manga. Podding comes after flowering sets in. The earliest flowering occurred at 38 DAP, while the earliest podding started at 43 DAP by 2M:2C + C2WBM and 3M:3C + M2WBC at Garu in the 2022 cropping season (**Table 5**). A maximum of 5 days came between flowering and pod formation. Effective podding was influenced by early flowering, as the same treatment flowered at 38 DAP. However, podding of cowpea is reported to vary genetically, but not due to environmental influences [22] [23]. (**Table 4** and **Table 5**).

Table 4. Days to 50% flowering of cowpea as affected by row arrangement and relative times of planting at Garu and Manga in 2021 and 2022.

Cropping systems		Days to 50% flowering					
		Garu			Manga		
Row arrangement (RA)	Relative times of planting (RTP)	2021	2022	Mean	2021	2022	Mean
1M:1C†	M2WBC#	42	39	41	40	41	41
	SIM	40	40	40	41	39	40
	C2WBM	42	38	40	41	40	41
2M:2C	M2WBC	41	39	40	40	40	40
	SIM	39	41	40	40	39	40
	C2WBM	40	38	39	41	40	41
3M:3C	M2WBC	42	38	40	39	39	39
	SIM	38	40	39	41	40	41
	C2WBM	41	40	41	41	40	41
Mean		41	39		40	40	
Sole maize		41	39	40	40	40	40
RA		HSD = NS p = 0.1691			HSD = NS p = 0.8063		
RTP		HSD = 1.011 p = 0.0338			HSD = NS p = 0.0965		
Year		HSD = NS p = 0.8085			HSD = NS p = 0.0998		
<u>Interactions</u>							
RA × RTP		HSD = NS p = 0.9329			HSD = NS p = 0.1561		
RA × Y		HSD = NS p = 0.4230			HSD = NS p = 0.8063		

Continued

RTP × Y	HSD = 0.378 p = 0.0004	HSD = 0.476 p = 0.01756
RA × RTP × Y	HSD = NS p = 0.5056	HSD = NS p = 0.8054

Note: †: 1M:1C = 1 row maize alternating with 1 row cowpea; 2M:2C = 2 rows maize alternating with 2 rows cowpea; 3M:3C = 3 rows maize alternating with 3 rows cowpea; #: M2WBC = Maize planted 2 weeks before cowpea; C2WBM = Cowpea planted 2 weeks before maize.

Table 5. Days to 50% to podding of cowpea as affected by row arrangement and relative times of planting at Garu and Manga in 2021 and 2022.

Cropping systems		Days to 50% podding					
		Garu			Manga		
Row arrangement (RA)	Relative times of planting (RTP)	2021	2022	Mean	2021	2022	Mean
1M:1C†	M2WBC#	47	45	46	44	45	45
	SIM	44	46	45	45	45	45
	C2WBM	47	43	45	45	46	46
2M:2C	M2WBC	47	44	46	45	46	46
	SIM	44	47	46	44	45	45
	C2WBM	46	43	45	45	45	45
3M:3C	M2WBC	47	43	45	44	45	45
	SIM	44	45	45	45	49	47
	C2WBM	47	46	47	46	46	46
Mean		46	45		45	46	
Sole maize		46	44	45	46	45	46
RA		HSD = NS p = 0.9267			HSD = NS p = 0.2720		
RTP		HSD = 1.19 p = 0.0110			HSD = 1.25 p = 0.0110		
Year		HSD = 0.80 p = 0.0055			HSD = 0.85 p = 0.0193		
<u>Interactions</u>							
RA × RTP		HSD = NS p = 0.5641			HSD = 0.76 p = 0.1992		
RA × Y		HSD = NS p = 0.9445			HSD = NS p = 0.4128		
RTP × Y		HSD = 0.445 p = 0.0013			HSD = NS p = 0.2962		

Continued

RA × RTP × Y	HSD = NS p = 0.9589	HSD = NS p = 0.0594

Note: †: 1M:1C = 1 row maize alternating with 1 row cowpea; 2M:2C = 2 rows maize alternating with 2 rows cowpea; 3M:3C = 3 rows maize alternating with 3 rows cowpea; #: M2WBC = Maize planted 2 weeks before cowpea; C2WBM = Cowpea planted 2 weeks before maize.

3.6. Total Grain Yield of Cowpea

There were highly significant effects of row arrangement, relative times of planting and year, but no significant interactions on total grain yield of cowpea during the data collection period. The treatment that dominated in the cowpea yield is row arrangement, when cowpea was planted 2 weeks before maize, followed by cowpea planted simultaneously, which was significantly higher than cowpea planted 2 weeks after maize. Cowpea planted before maize and cowpea planted simultaneously with maize tend to start growth early, spread their leaves widely and attract more radiation for high photosynthates or assimilate production, hence effective phenological and vegetative growth and consequently higher yields. Cowpea planted 2 weeks before maize produced the highest cowpea grain yield of 3.22 t/ha at Garu, less than the cowpea grain yield of 3.79 t/ha obtained at Manga. These results were due to the different environmental conditions experienced at both experimental sites. The early cowpea also had a head start for cowpea planted 2 WBM, allowing component crops to effectively use the available growth resources. The yields of the intercrop cowpea were higher than the sole cowpea because of the interaction effect of component crops, which the sole cowpea did not experience. These findings contradicted Several previous studies that reported lower intercrop yields for cereal-legume trials [10] [24] [25]. According to [14], competition among component crops for growth factors such as light, available water and nutrients, and root space is among the crucial factors that determine the variations in their productivity levels. [26] [27] also stated that crop yield is strongly tied to competition between intercrops. This means the competitiveness is negative, crop yield would reduce, but minimal competition may not affect crop yield (**Table 6**).

Table 6. Total Grain yield of cowpea as affected by row arrangement and relative times of planting at Garu and Manga in 2021 and 2022.

Cropping systems		Cowpea Grain Yield (t/ha)					
		Garu			Manga		
Row arrangement (RA)	Relative times of planting (RTP)	2021	2022	Mean	2021	2022	Mean
1M:1C†	M2WBC#	1.91	2.15	2.03	1.98	3.46	2.72
	SIM	2.26	1.72	1.99	1.96	3.59	2.78
	C2WBM	2.52	3.22	2.86	2.64	3.79	3.22

Continued

	M2WBC	1.70	2.21	1.96	1.86	2.82	2.34
2M:2C	SIM	1.19	1.51	1.35	1.37	2.21	1.79
	C2WBM	2.52	2.29	2.41	2.25	2.71	2.48
	M2WBC	1.27	1.42	1.35	1.25	1.90	1.58
3M:3C	SIM	0.93	1.22	1.08	1.07	1.63	1.35
	C2WBM	1.49	1.36	1.43	1.56	2.17	1.87
Mean		1.56	1.90		1.97	3.00	
Sole Cowpea		1.56	1.59	1.97	2.17	2.84	2.51
RA			HSD = 482.4 p = 0.0001			HSD = 486.54 p < 0.0001	
RTP			HSD = 482.4 p = 0.0031			HSD = 486.54 p = 0.0131	
Year			HSD = NS p = 0.9263			HSD = 330.37 p < 0.0001	
Interactions							
RA × RTP			HSD = NS p = 0.5426			HSD = NS p = 0.5322	
RA × Y			HSD = NS p = 0.9690			HSD = NS p = 0.1659	
RTP × Y			HSD = NS p = 0.9724			HSD = NS p = 0.6445	
RA × RTP × Y			HSD = NS p = 0.9111			HSD = NS p = 0.5565	

Note: †: 1M:1C = 1 row maize alternating with 1 row cowpea; 2M:2C = 2 rows maize alternating with 2 rows cowpea; 3M:3C = 3 rows maize alternating with 3 rows cowpea; #: M2WBC = Maize planted 2 weeks before cowpea; C2WBM = Cowpea planted 2 weeks before maize.

4. Conclusion

The intercropping systems largely enhanced the growth and development of the component crops compared with the sole crops. Generally, planting maize 2 weeks before cowpea or simultaneously with cowpea enhanced the growth and development of the maize component crop. The 1M:1C and 2M:2C row arrangements also enhanced the growth and development of the maize. The growth and development of the cowpea were enhanced when cowpea was planted 2 weeks before maize and at row arrangements of 2M:2C and 3M:3C. Planting maize and cowpea simultaneously (SIM) at 2M:2C produced the largest maize yield, followed by planting maize 2 WBC at 2M:2C. The least maize yield was produced by 3M:3C + C2WBM while the highest cowpea yield was obtained when cowpea was planted 2 WBM at 1M:1C followed by planting maize and cowpea simultaneously (SIM) at 1M:1C.

Recommendation

It is therefore recommended that farmers with a high priority for maize yield should adopt planting 2 rows of maize alternating with 2 rows of cowpea and planting the two crops simultaneously (*i.e.* 2M:2C + SIM) for maximum yield. However, farmers with priority for cowpea yield should adopt a spatial arrangement of 1 row of maize alternating with 1 row of cowpea and planting cowpea 2 weeks before maize (*i.e.* 1M:1C + C2WBM) to maximize yield.

Conflicts of Interest

The authors declare no conflicts of interest.

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