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Weeding and Plant Density Effects on Weed Density, Agronomic Traits and Grain Weight of Cowpea (*Vigna unguiculata*) in Sierra Leone

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Abstract A study was conducted in 2011 to determine the effects of 3 weeding and 3 plant density levels on weed density, agronomic traits and grain weight of cowpea. The experiment was laid out in randomized complete block design, with 3 replications. The results indicate the occurrence of broadleaf plants, grasses and sedges. Twenty-seven weed species, belonging to 25 genera and distributed in 14 families were identified. The dominant weeds were *Diodia scandens*, *Croton hirtus*, *Oldenlandia herbacea* and *Cyperus difformis*. The results showed that weeding and plant density levels significantly ($p<0.05$) affected the performance of agronomic traits of cowpea cultivars [IT86D-721 and Musia]. Even though weeding had no significant effect ($p<0.05$) on undamaged pods, the largest mean undamaged pods was recorded in plots weeded at 3 and 6 weeks after planting; while the least was recorded in un-weeded plots (control). Grain weight of cowpea was not significantly ($p<0.05$) affected by weeding, but was significantly ($p<0.05$) affected by plant density levels. Weeding every 3 and 6 weeks, and planting at lower density was adequate to enhance lower weed density, good vegetative growth and higher grains weight of cowpea in the study area.

Keywords *Vigna unguiculata*, Weed, Weeding, Plant Density, Agronomic Traits, Grain Weight

1. Introduction

Cowpea [*Vigna unguiculata* (L.) Walp] is of vital importance to the livelihood of millions of people in Sierra Leone, and other parts of the world, including the semi-arid tropics that includes parts of Asia, Africa, Central and South America, and Southern Europe[44, 27]. In Sierra Leone and many other poverty stricken parts of sub-Saharan Africa, cowpea [*Vigna unguiculata* (L) Walp] has emerged to be very popular, unique and the cheapest alternative source of protein for millions of consumers. Besides being a cheap source of protein, cowpea has many other benefits including; food for man and livestock[43, 45], revenue-generating commodity for farmers and grain traders[40, 29, 9], important for controlling soil erosion and fixing atmospheric nitrogen into the soil[30, 10], and also improve the health of women and children[16].

The major cowpea producing areas in Sierra Leone are; Northern region (Kabala), Western area and Southern region; with Moyamba District (southern Sierra Leone) producing the largest, compared with other regions in the country. Yield estimate of about 1.5 tons/ha, and with good consumer quality have been reported for improved cowpea varieties[32]. However, the average yield of cowpea in Sierra Leone is much lower, compared with other leading countries like Nigeria. The impressive increase in yield reported in Nigeria is due to the significant advances made by the International Institute of Tropical Agriculture (IITA), in developing and releasing a number of cowpea varieties with different maturity periods; and resistance to several diseases, insect pests and parasitic weeds[44]. Although breeding for resistance to diseases and pests has achieved considerable progress in the past, it has however been reported that resistance is not durable, and may vary from one agro-ecology to another[1]. Many of the cowpea varieties[e.g. Slipea 1, Slipea 2 and 1190] released by National Agricultural Research Center[NARC] as resistant to specific pest's species, and high yielding still continue to be problematic under local farmer's condition. This makes it imperative for the re-evaluation of such released varieties/genotypes under Sierra Leone's agro-ecological condition. Multi-location trials, especially those focused on problems related to weeds, pests and diseases in different agro-ecologies in Sierra Leone will be helpful in identifying the most adaptable varieties suitable for the different regions

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in the country. Researchers working on cowpea have reported that the crop is highly susceptible to weed infestation[41, 11, 39 and 18], insect pests[26 and 6] and diseases[27]. Crop losses by weeds could be aggravated by delay in weeding or inability to weed throughout the entire crop growth period. Generally weeds reduce crop yields and quality by competing for nutrients, water and space. According to[21] estimates, up to 40% crop harvest in developing countries is lost due mainly to adverse effects of weeds, diseases and insect pest attacks.[47] reported yield loss within the range of about 50 to 80 % due mainly to high weed infestation. More importantly, weeds may act as reservoirs or alternate hosts for insects, diseases and nematodes[26]. Subsistence farmers of the tropics spend more time, energy and money for weed control than any other aspect of crop production. Thus, the best weeding regime needs to be found out for cowpea in Sierra Leone, with a view to increase vegetative growth attributes and yield.[50] have shown that the presence of weeds in crop fields may contribute to increase in insects and disease infestations.[2] reported that reduced cowpea biomass, flowers, pods and grain yields were associated with cowpea plots where weeds and insect pests were not controlled. They also observed that weed control without insect pests control resulted in more than 90 % reduction in cowpea yield and yield components. More information is needed on these pests to evaluate the extent of damage in farmers' fields in Sierra Leone.

Conflicting reports from various researchers have been published on the effect of plant density/between row-spacing on agronomic traits of cowpea and other grain legumes grown in many countries. Some results have indicated that increasing plant density/between row-spacing significantly affects cowpea growth parameters; including plant height, stem girth, number of branches, number of leaves and leaf area index.[24] reported that inappropriate planting geometry as practiced by most African farmers, leading to competition for site resources, is the principal reason for the low pea-barley intercrops productivity.[49] found that plants produced at highest densities were taller and more sparsely branched. On the contrary,[35] reported that plant population had no significant effect on plant height.[5] showed that planting arrangement of two rows of cowpea after every two rows of maize (*Zea mays* L.) gave greater grain yields for both crop components and greater land equivalent ratio than a one-to-one row system. So far, data on the effects of planting density on yield components of different cowpea genotypes, weeds and insect pest's population density are inadequate in the African context. Even where studies have been conducted, there is great need for a review of the current status of the results obtained. Differences among cultivars in plant height and number of leaves produced per plant have been reported by[34] and[36]. They both found that increasing plant density decreased plant height and number of leaves per plant. These results are in agreement with the findings of many other researchers[31, 4]. They showed that increasing plant density reduced the number of branches per plant, leaf area index; and that the local cultivar had the greatest number of branches and leaf area index per plant than other cultivars.[49 and 23] reported that plants produced at highest densities set fewer pods than those at the lowest densities.[42] and[35], on the other hand found that plant population had no significant effect on number of seeds per pod. Decreased plant population has been found to result in increased 100-seed weight. This may have been due to better availability of nutrients, better translocation of photosynthates from source, and higher accumulation of photosynthates in the seeds. Contrasting results have however been reported by[46] and[35]. They found that 100-seed weight was not affected by plant population.[25] found that the highest seed yield was obtained with higher plant density. For Sierra Leone, although some work has been done on insects and diseases of cowpea in the past, no such data is available for weeds and plant density. Keeping the above facts in view, the present study was conducted to determine the most appropriate weeding time and optimum planting density for getting control over weeds resulting in increased growth performance and grain yield of cowpea.

2. Materials and Methods

2.1. Description of Experimental Site, Design and Data Collection Procedures

A field experiment was conducted in the upland soils of Njala, close to the National Agricultural Research Center[NARC] and the former Agronomy building of Njala University in 2011. The University is situated at 8^0 07'north-latitude and 12^0 05' west-longitudes[48]. The climate in the Njala area is characterized by a pronounced rainy season[May to November], and a pronounced dry season[December to April]. The average rainfall is 108 inches[2750 mm] annually[48]. The mean monthly air temperature is nearly constant, varying from 76.6^o F[24.8°C] in August to 82.4^o F[28.0°C] in March. Maximum temperatures occur in March and April, and minimum in July and August (mean monthly maximum of 27°C to 28°C). Mean monthly minimum temperatures in December, January and February are 14°C to 20°C. During the remainder of the year minimum temperatures vary little from 20 °C to 23°C. Land at Njala is relatively flat and the soil is gravely loamy, highly weathered, well drained and rich in organic matter[48].

Planting was done on 5^{th} September 2011. Treatments consisted of three weeding regimes viz., one-hoe weeding at 3 weeks after sowing, two-hoe weeding at 3 and 6 weeks after sowing, and un-weeded (control); designated as W_1, W_2 and W_0, respectively; and three planting densities viz., 456522, 239130 and 152174 plants ha^{-1}; designated as P_1, P_2 and P_3 respectively. The experiment was laid out in RCBD (Randomized Complete Block Design), and replicated three times. The experimental plot measured 2.3m x 1.2m, and the whole experimental field measured 49.9m x 5.6m ($279.44m^2$). There were 18 plots for each combination of treatments and the replications and the treatments were; allocated to each plot randomly by balloting without replacement.

Musia [local] and IT86D-721/Slipea 2[Improved] were cowpea varieties used for the study. Musia is a local variety; has an erect growth habit, produced fewer branches, grows taller, seeds are brown with black-eyes and it is early maturing. IT86D-721 [otherwise called Slipea 2], is an improved cowpea variety, tested and release by NARC[Njala Agricultural Research Center] to farmers in Sierra Leone. IT86D-721 has an erect growth habit, produces several branches, and the seeds are white with black-eyes. Three seeds were sown per hole at a depth of 2.5cm and at a spacing of 50cm × 10 cm, 50cm x 20cm and 50cm x 30cm respectively; and later thinned to 2 seedlings per stand, at 2 weeks after planting (WAP).

Samples of weeds within 0.25m^2 quadrate were collected, identified and classified based on floral morphology (broadleaf, sedges and grasses). The quadrate was thrown twice per plot. Sampling was done at 3, 6 weeks after planting and prior to harvest. Except for plots designated as W_0[un-weeded/control], all different weed species within each quadrate were harvested at soil level, separated into different types, and then counted to obtained the quantity of different weed species present. At harvest time, the same process was repeated in all plots designated as W_0 to have a good estimates of weed species present. In order to determine the dry matter accumulation at each sampling period, all weed species collected per plot were tied together, weighed to obtain the fresh weight and then oven dried to a constant weight.

Data collection on vital growth attributing characters included; plant height (cm), number of leaves, leaf area (cm^2) and stem girth (cm). Five (5) sample plants from the middle rows of each plot, excluding the border plants were targeted for data collection. Data collection commenced at 2 weeks after planting, and continued respectively at 4, 6 and 8 weeks after planting (WAP). The height of the cowpea plant was measured to the nearest centimetre from the base to top. The mean height from the 5 randomly selected plants from the two middle rows was taken as the score for each plot. The diameter of the stem was measured to the nearest centimetre at the base of the cowpea plant from 5 randomly selected plants from the two middle rows per plot and used to compute the mean stem girth score for each plot. The number of leaves per plant was determined by counting and the data from 5 plants from the two middle rows was used to compute the score for each plot.

Data collection on yield attributing characters included; number of pods at 50% flowering, number of dry pods at harvest, number of damaged and undamaged pods at harvest, total grains weight (g) and stover/folder weight (g).

2.2. Statistical Analysis

The number of weed species within each experimental unit was analyzed by calculating the total number of each weed species to obtain the population density throughout the data collection period. The crop data [plant height, number of leaves, leaf area and stem girth] and weed data [weed density and biomass] collected were pooled together and the means used for analysis. The acquired data were analysed using Genstat Statistical Package, and analysis of variance was performed to obtain the variance and treatment means. The means were separated using the Fisher's Least Significant Difference (LSD).

3. Results and Discussion

Table 1 shows the checklist of weed species identified in cowpea experimental field at Njala in 2011. A total of 27 different weed species belonging to 25 genera and within 14 plant families were identified in the experimental site throughout the study period. The distribution of the weed species was random and frequency of occurrence varied across treatments. Other researchers working on cowpea in Nigeria recorded 17 different weed species[38]. Majority of the weeds in the experimental site were broadleaf plants (dicotyledons) (15,857) (90.03%), while sedges (1,584) (8.99%) and grasses (174) (0.99%) (monocotyledons) were found in lesser densities [Table 1]. The dominant weeds flora infesting cowpea during the growing season were *Diodia scandens* S.W [Rubiaceae], *Croton hirtus*[Euphorbiaceae], *Oldenlandia herbacea* (Rubiaceae) *and Cyperus difformis* (Cyperaceae). They had relative weeds densities of (8,849) (50.24%), (3,955) (22.45%), (2,644) (15.01), and (1,564) (8.88%) respectively. Weeds have been defined as higher plants in the agro-ecosystem; which are not sown, undesired, out of place or generally as plants which do more harm than good[12]. It has been observed that, the degree of damage by a particular type of weed is directly related to the level of weed infestation/density. Weeds have been reported to significantly contribute to direct yield losses of crops by competing for water, nutrients, light, space and/or carbon dioxide[22, 11, and 17].[47] reported that 50 to 80 % crop yield loss is caused by weeds, probably due mainly to delay in weeding. In addition to competition for limited growth resources, it has also been generally observed that weeds also act as reservoirs or alternate hosts for insects, diseases and nematodes[26 and 15], with attendant negative consequences on growth and yield[3].[19] associated the degree of damage caused by weeds to be a function of plant leaf area index. Other growth characteristics of some of the weedy plants that may have given them competitive advantage over cowpea varieties sharing the same habitat include; the number of leaves produced, number of branches, shape and broadness of leaves produced, pattern of canopy/plant architecture and height. This might explain the reason for the significant effect of weeds on most of the agronomic traits measured in this study.

Table 1. Composition of weed species in cowpea field at Njala, southern Sierra Leone[2011]

No	Weed species	Family	Class	Density	%
1	*Croton hirtus*	Euphorbiaceae	B	3955	22.45
2	*Diodia scandens* S.W	Rubiaceae	B	8849	50.24
3	*Oldenlandia herbacea*	Rubiaceae	B	2644	15.01
4	*Cleome ciliate*	Capparidaceae	B	5	0.03
5	*Mimosa pudica*	Leguminosae /Mimosaceae	B	3	0.02
6	*Mitracrpus scaber*	Rubiaceae	B	162	0.92
7	*Pueraria phaseoloides*	Leguminosae /Popilionadeae	B	52	0.30
8	*Lindania diffusa*	Scrophulariaceae	B	6	0.03
9	*Acacia mangium*	Fabaceae	B	32	0.18
10	*Mallugo nudicanlis*	Molluginaceae	B	76	0.43
11	*Phyllanthus sublanatus*	Euphorbiaceae	B	1	0.01
12	*Sida sp.*	Malvaceae	B	2	0.01
13	*Starchytarpheta sp.*	Verbenaceae	B	2	0.01
14	*Spigelina anthelmia*	Loganioneae	B	12	0.07
15	*Commenlina benghalensis*	Commelinaceae	B	7	0.04
16	*Eupatorium africanum*	Compositae	B	1	0.01
17	*Desmodium laxiflorum*	Fabaceae	B	2	0.01
18	*Elenthenanthera ruderalis*	Compositae	B	24	0.14
19	*Clerodendron violaceum*	Verbanaceae	B	2	0.01
20	*Cassia sp.* (introduced)	Leguminosae /Caesalpinoideae	B	20	0.11
	Subtotal			15857	90.03
21	*Cyperus sphacelatus*	Cyperaceae	S	2	0.01
22	*Cyperus sp.*	Cyperaceae	S	18	0.10
23	*Cyperus difformis*	Cyperaceae	S	1564	8.88
	Subtotal			1584	8.99
24	*Andropogon tectorum*	Gramineae/Poaceae	G	137	0.78
25	*Pennisetum subangustum*	Gramineae/Poaceae	G	9	0.05
26	*Panicum maximum*	Gramineae/Poaceae	G	18	0.10
27	*Rottboellia exaltata*	Gramineae/Poaceae	G	10	0.06
	Subtotal			174	0.99
Total				17,615	

Note: B = Broadleaf plant, S = Sedge, G = Grass

Table 2 shows effect of cowpea genotypes, weeding regimes and plant density levels on weed density. Weed density was significantly (P< 0.05) affected by cowpea varieties [table 2]. Plots sown with the local cowpea variety[musia] had the highest mean weed density [127.4] than plots sown with the improved cowpea variety [IT86D -721/Slipea 2] [82.6]. Several factors could be responsible for the variation in weed densities recorded per variety. Among these may be the differences in genetic make-up, morphology and allelopathic potential of the two cowpea varieties. Both cowpea varieties are broadleaf plants, which mean that both have the potential to suppress weed growth, although variation appears to occur in their suppressive power. Although the leaf area of Musia appears to be slightly larger than that of IT86D-721, it is possible that because IT86D-721 [improved cowpea variety] have the potential to produce more active allelopathtic compounds[poisonous substances that have the potential to inhibit plant growth, and also are lethal to other living organisms sharing the same habitat] than Musia-local, may have significantly (P<0.05) contributed to the low weed density recorded in plots sown with IT86D-721[improved cowpea variety]. The morphological characteristics of the two varieties may have also contributed to the variation in weed density. The local variety has lesser competitive advantage over the improved variety in suppressing weed density, because it is an erect variety with open and sparse canopy, thus giving rise to adequate light penetration that may have permitted weed germination, growth and development. The improved variety, on the other hand has more competitive advantage in reducing weed density because it forms a relatively thicker canopy which do not only suppressed weed growth and development, but also reduced their dry matter accumulation and hence lesser weed weight/biomass. More studies need to be conducted to actually confirm the reason/s for the differential in weed density between the two cowpea genotypes.

As indicated in table 2, weeding regime and plant density levels had no significant ($P < 0.05$) influence on the population of weeds recorded during the experimental period. However, the un-weeded (control) plots had a statistically higher mean weed density (121.6) than plots that were weeded once at 3 weeks (102.3) and twice at 3 and 6 weeks after planting (91.1). Based on result obtained, weeding twice at 3 and 6 weeks after planting, had the least weed density (91.1), and thus the most recommended period for weeding cowpea plot. From this study, it is thus clear that weeds tend to increase in density in plots that are un-weeded; compared with where weeding is done only once and twice. Plots weeded more than once tends to have lesser amount of weed seeds deposited in the weed seed-bank. This is because weedy plants that are removed at the early growth stage are prevented from becoming fully established; hence lack the potential to produce more seeds. Plots with higher plant density (456522 plants ha^{-1}-spacing of 50cm x 10cm) had a statistically higher mean weed density (117.1) than plots with smaller plant densities of 239130 plants ha^{-1}[50cm x 20cm - control] (93.0) and 152,174 plants ha^{-1}[50cm x 30cm] (104.9) (table2). There is a need to further investigate this aspect of the study.

Tables 3 and 4 give information on the effect of weeding regime and plant density levels on fresh and dry weight of weed species collected in this study. As indicated in table 3, weeding regime highly significantly ($P<0.05$) affected the fresh and dry weed weight. The un-weeded plots (control) had the highest fresh and dry weed weight, than plots weeded once at 3 weeks after sowing and twice at 3 and 6 weeks after sowing. Even though plant density levels had no significant ($P<0.05$) effect on both fresh and dry weed weight, fresh and dry weed weight[biomass] was highest in plots with smaller plant density [152174 plants ha^{-1}-50cm x 30cm] and least in plots with higher plant density [456522 plants ha^{-1}-50cm x 10cm] [table 4]. This finding is in agreement with observations made by many other researchers [6, 7 and 8]. They reported that weed biomass increased as the row-spacing increases and planting density decreased. In their work, it was concluded that weed biomass was highest at widest row spacing than at closer spacing; because wider row spaces provide adequate space for less competition for nutrients and light among weed species thriving in the same plot.

Table 2. Effects of cowpea genotypes, weeding regimes and plant density on weed density

Variety	Weeding regime			Varietal Means	Plant density			Varietal means
	W_0	W_1	W_2		P_1	P_2	P_3	
IT86D-721	102.0	67.6	78.2	82.6*	91.1	78.2	78.4	82.6*
Musia	141.1	137.1	104.0	127.4*	143.0	107.1	131.4	127.4*
Mean	121.6ns	102.3ns	91.1ns		117.1 ns	93.0 ns	104.9 ns	
LSD ($P < 0.05$)	52.87			LSD ($P < 0.05$)	53.8			
CV (%)	76.1			CV (%)	76.9			

**** = significant ($P < 0.05$); ns = Not significant ($P > 0.05$).**
W_0 = No-weeding, W_1= One-hoe weeding @ 3 weeks after sowing, W_2 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P_1= 456,521.7391 plants ha^{-1}[50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1}[50cm X 30cm]

Table 3. Effects of cowoea genotypes and weeding regimes on weed biomass

Variety	Fresh weed weight			Varietal Means	Dry weed weight			Varietal Means
	W_0	W_1	W_2		W_0	W_1	W_2	
IT86D-721	852.0	214.0	242.0	436.0 ns	182.9	44.6	47.0	91.5 ns
Musia	1071.0	290.0	330.0	564.0 ns	242.8	59.3	68.9	123.7 ns
Mean	961.0*	252.0*	286.0*		212.9*	52.0*	57.9*	
LSD ($P < 0.05$)	34.0			LSD ($P < 0.05$)	64.68			
CV%	54.7			CV%	62.8			

*** = significant ($P < 0.05$); ns = Not significant ($P < 0.05$).**
W0 = No-weeding, W2= One-hoe weeding @ 3 weeks after sowing, W3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing

Table 4. Effects of cowpea genotypes and plant density on weed biomass

Variety	Fresh weed weight			Varietal Means	Dry weed weight			Varietal means
	P_1	P_2	P_3		P_1	P_2	P_3	
IT86D-721	351.0	467.0	489.0	436.0 ns	71.4	100.6	102.5	91.5 ns
Musia	557.0	499.0	634.0	564.0 ns	127.7	103.5	139.8	123.7 ns
Mean	454.0 ns	483.0 ns	562.0 ns		99.5 ns	102.1 ns	121.1 ns	
LSD (P <0.05)	261.7			LSD (P <0.05)	64.68			
CV%	54.7			62.8				

ns = Not significant (P > 0.05).
P1= 456,521.7391 plants ha-1[50cm X 10cm], P2 = 239,130.4348 plants ha-1[50cm X 20cm], P3 = 152,173.913 plants ha-1[50cm X 30cm]

The leaf area indices recorded for both the local and improved cowpea cultivars differed significantly ($P < 0.05$), and was significantly ($P < 0.05$) affected by plant density levels[table 5]. The local variety[Musia] had larger leaf area than the improved variety[IT86D-721]. Based on plant density levels, plots with higher plant density[456522 plants ha^{-1}] produced a larger leaf area than plots with lesser plant densities[239130 plants ha^{-1}] and 152174 plants ha^{-1}[50cm x 30cm] respectively. However, plots with plant density of 152174 plants ha^{-1} had a larger leaf area than plots with plant density of 239130 plants ha^{-1}[50cm x 20cm][Table 5]. Base on this finding, it can be noted that the closer the space between plants stands, and the higher the plant density, the greater the potential for increased leaf area. This finding agrees with those of Carson (1971), who found that high plant densities led to high leaf area indices in wheat and *Phaseolus spp*, respectively. In a density trial ranging from 160.4 to 445.7 x 10^3 bambara bean plants per hectare,[14] also observed leaf area index[LAI] to increase with increasing density. The higher leaf area per plant may have also been due to reduced competition from weeds, and increased availability of resources like nutrients, soil moisture and light. These results are also in conformity with the findings of[28 and 20].

Table 5. effect of cowpea genotypes and plant density on leaf area (cm^2)

Variety	Plant density levels			Variety mean
	P_1	P_2	P_3	
IT86D-721	34.97	31.33	37.73	34.68*
Musia	61.61	57.61	55.35	58.19*
Mean	48.29*	44.47*	46.54*	
LSD (P <0.05)	4.943			
CV%	22.8			

*** = Significant at p < 0.05**
P1= 456,521.7391 plants ha-1[50cm X 10cm], P2 = 239,130.4348 plants ha-1[50cm X 20cm], P3 = 152,173.913 plants ha-1[50cm X 30cm]

Weeding regime and plant density significantly ($P < 0.05$) affected plant height of the two cowpea cultivars[Table 6]. Based on the findings, one-hoe weeded plots[at 3 weeks after planting] had the highest plant height than the un-weeded control plots. Weeding facilitates plants to have more resources for growth. These results agreed with[20]. They found that, increasing weeding times increased plant height, due to efficient weed control.

Plant height also differed significantly ($P < 0.05$) based on the level of plant densities[table 8]. Plant density of 456522 plants ha^{-1}[50cm x 10cm] recorded the highest plant height, while the least was recorded at plant density of 239130 plants ha^{-1}[50cm x 20cm] and 152174 plants ha^{-1}[50cm x 30cm]. However plant density of 152174 plants ha^{-1}[50cm x 30cm] recorded the height plant height than plant density of 239130 plants ha^{-1}[50cm x 20cm]. Looking at the two, it appeared that plant height have the potential to increase the wider the spaced between plant stands, and the lesser the population density. A repeat of this experiment is however needed to confirm result obtained.

Table 6. Effects of weeding regime and plant density on plant height of cowpea varieties

Weeding regime	Plant density			Weeding regime Mean
	P_1	P_2	P_3	
W_0	45.6	53.0	60.1	52.9*
W_1	61.0	48.5	60.9	56.8*
W_2	61.3	50.4	42.4	51.4*
Plant density Mean	56.0*	50.6*	54.5*	
LSD (P <0.05)	16.67			
CV%	54.4			

*** = significant at (P < 0.05)**
W0 = No-weeding, W2= One-hoe weeding @ 3 weeks after sowing, W3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P1= 456,521.7391 plants ha-1[50cm X 10cm], P2 = 239,130.4348 plants ha-1[50cm X 20cm], P3 = 152,173.913 plants ha-1[50cm X 30cm]

As shown in table 7, weeding regime and plant density significantly ($P < 0.05$) influenced stem girth/diameter of the two cowpea varieties. The un-weeded/control plots recorded the largest stem girth than the one-hand and two-hand weeded plots. Comparatively, the one-hand weeded plots recorded the largest stem girth, while the two-hand weeded plots recorded the least stem girth. The influence of weeding regimes on stem girth in this study is not clear, and the need to investigate further.

Plant density of 456522 plants ha^{-1}[closer spacing-50cm x 10cm] recorded the least stem girth, while plant density of 239130 plants ha^{-1}[50cm x 20cm] and 152174 plants ha^{-1} [wider spacing-50cm x 30cm], respectively recorded the largest stem girth. The larger stem girth recorded at plant density of 152174 plants ha^{-1}[50cm x 30cm] could be attributed to the wider spacing between the plant stands, favourable moisture regime and soil nutrient conditions. From this finding, it can be noted that the wider the space between plants stands, the better the potential for increase in stem girth/diameter.

Table 7. Effects of weeding regime and plant density on stem girth of cowpea varieties.

Weeding regime	Plant density			Weeding regime Mean
	P_1	P_2	P_3	
Wo	0.2978	0.3173	0.3839	0.3330*
W_1	0.2874	0.3176	0.3854	0.3302*
W_2	0.3225	0.3241	0.3035	0.3167*
Plant density Mean	0.3026*	0.3197*	0.3576*	
LSD (P < 0.05)	0.04966			
CV%	26.6			

*** = significant (P < 0.05)**
W0 = No-weeding, W2= One-hoe weeding @ 3 weeks after sowing, W3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P1= 456,521.7391 plants ha-1[50cm X 10cm], P2 = 239,130.4348 plants ha-1[50cm X 20cm], P3 = 152,173.913 plants ha-1[50cm X 30cm]

The number of fully expanded leaves produced by the two cowpea varieties differed significantly. Plant density levels affected the number of leaves produced by the cowpea genotypes, but was not significantly (P<0.05) affected by weeding regimes. As shown in table 8, plots with plant density of 152174 plants ha^{-1}[50cm x 30cm] produced the highest number of leaves, while plots with plant density of 456522 plants ha^{-1}[50cm x 10cm] and 239130 plants ha-1[5-cm x 20cm] respectively produced the least (Table 8). This implies that, the wider the spaced between plant stands the greater the potential for plants to produce higher number of leaves; and conversely, the closer the spacing, the lesser the number of leaves produced. This however depends on the soil nutrient status, moisture and other growth resources.

Even though there appeared to be no significant difference (P<0.05) between the numbers of pods counted for the two cowpea varieties at 50% flowering, the mean number of pods counted however differed. More pods were counted in plots sown with the local variety[Musia] than the improved variety[IT86D-721] at 50% flowering[Table 9]. Weeding regime significantly (P<0.05) affected the number of pods counted at 50% flowering, but was not significantly (P<0.05) affected by plant density levels. The un-weeded plots recorded more pods than the one-hand and two-hand weeded plots. Also the one-hand weeded plots recorded more pods than the two-hand weeded plots. This finding is not quite clear, and thus requires further investigation. Although there was statistically no significant difference (P<0.05) between the number of pods counted at 50% flowering and plant density levels, plots with lower plant densities[239130 plants ha^{-1} and 152174 plants ha^{-1}] however recorded more pods, than plots with higher plant density[456522 plants ha^{-1}[50cm x 10cm-closer spacing][Table 9]. The higher number of pods counted at 50% flowering in plots with lower plant density may be attributed to the lower level of competition between the crop plants and weeds on one hand, and also due to lower insect pests population density in such environments. Where plants are well spaced and plant density small, insects lack the potential to identify more alternative host plants, either as source of food, shade or facilitates spread and establishment, than in plots where plant density is high.

Table 8. Effects of cowpea genotypes, weeding regime and plant density on number of leaves produced

Variety	Weeding regime			Varietal Means	Plant density			Varietal means
	W_0	W_1	W_2		P_1	P_2	P_3	
IT86D-721	52.2	47.3	43.3	47.6*	40.4	46.9	55.4	47.6*
Musia	27.8	28.2	27.6	27.9*	24.4	28.1	31.0	27.9*
Mean	40.0ns	37.7ns	35.4ns		32.4*	37.5*	43.2*	
LSD (P < 0.05)	6.06			LSD (P < 0.05)	6.06			
CV%	48.8			CV%	48.8			

**** = significant (P < 0.05); ns = Not significant (P > 0.05).**
W0 = No-weeding, W2= One-hoe weeding @ 3 weeks after sowing, W3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P1= 456,521.7391 plants ha-1[50cm X 10cm], P2 = 239,130.4348 plants ha-1[50cm X 20cm], P3 = 152,173.913 plants ha-1[50cm X 30cm],

Table 9. Effects of cowpea genotypes, weeding regime and plant density on number of pods counted at 50% flowering

Variety	Weeding regime			Varietal Means	Plant density			Varietal means
	W_o	W_1	W_2		P_1	P_2	P_3	
IT86D-721	4.02	2.48	1.76	2.75ns	2.46	2.81	2.98	2.75ns
Musia	3.72	3.86	2.85	3.48ns	3.49	2.91	4.04	3.48ns
Means	3.87**	3.17**	2.30**		2.98ns	2.86ns	3.51ns	
LSD (P < 0.05)	2.260			LSD (P < 0.05)	2.260			
CV%	43.7			CV%	43.7			

**** = highly significant (P < 0.05); ns = Not significant (P > 0.05).**
W_0 = No-weeding, W_2= One-hoe weeding @ 3 weeks after sowing, W_3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P_1= 456,521.7391 plants ha^{-1}[50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1}[50cm X 20cm], P_3 = 152,173.913 plants ha^{-1}[50cm X 30cm]

The number of pods harvested was not significantly (P > 0.05) affected by the two cowpea varieties and weeding regime. However, more pods were harvested from the improved cowpea variety[IT86D-721] than the local variety[Musia]. The one-hand weeded plots produced more pods than the zero-weeded and two-hand weeded plots[table 10].

The number of pods harvested differed highly significantly (P > 0.05) across the plant density levels. The lowest number of pods harvested was recorded in plots with plant density of 456522 plants ha^{-1}, while the highest number of pods was harvested in plots with plant density of 239130 plants ha^{-1} and 152174 plants ha^{-1} respectively. Comparatively, a relatively larger number of pods harvested were recorded in plots with plant density of 152174 plants ha-1 than in plots with plant density of 239130 plants ha-1[Table 10]. The wider space between plants and the fertility status of the site may have largely contributed to the greater number of pods produced, compared with where plants are more closely spaced. With less or no competition threat for moisture, nutrients, light, air, etc; plants that are well spaced have the potential to grow better, compared to where competition is high. This may explain the reason for the larger number of pods harvested in plots where plants are widely spaced than in plots where plants are clustered together.

The number of pods damaged differed significantly (P<0.05) between the two cowpea varieties. The improved variety[IT86D-721] had more damaged pods than the local variety[Musia]. Even though weeding regime did not significantly (P<0.05) affects number of pods damaged; the un-weeded plots had more damaged pods than one-hand and two-hand weeded plots. The least number of pods damaged were recorded in two-hand weeded plots[Table 11]. The higher number of damaged pods recorded in un-weeded plots could be attributed to high weed density, hence high level of competition for the limited growth resources. This implies that, the lesser the competition between plants for growth resources, the more potential for increase in number of pods. Plant density levels highly significantly (P<0.05) affected the number of pods damaged. More damaged pods were harvested in plots with lower plant density[152174 plants ha^{-1}] than in plots with higher plant densities[456522 plants ha^{-1} and 239130 plants ha^{-1}][Table 11].

From result obtained in table 12, there was no significant difference (P<0.05) between the numbers of undamaged pods recorded for the two cowpea varieties. However, the local variety[Musia] recorded more undamaged pods than the improved variety[IT86D-721]. Even though weeding regime had no significant (P<0.05) effect on numbers of undamaged pods, the largest number of undamaged pods was however recorded in the one-hand and two-hand weeded plots; while the least was recorded in un-weeded plots. This implies that; in addition to moisture, nutrient condition in the soil, light; a weed-free condition are ideal for better plant growth, than in situations where these conditions are limited. The better plots are weeded, the more the expected number of pods produced, and the less the number of undamaged pods.

The number of undamaged pods recorded was highly significantly (P<0.05) affected by plant density levels. Plant density of 152174 plants ha^{-1} recorded the largest number of undamaged pods, while the least was recorded in plots with plant density of 239130 plants ha^{-1} and 456522 plants ha^{-1}[Table 12]. The larger number of undamaged pods recorded in plots with plant density of 152174 plants ha^{-1} may be attributed to the lower plant density and wider spacing between plant stands. The wider the spaced between plant stands, the lesser the competition for growth resources[moisture, nutrients, etc]. This observation is consistent with those of other workers. For example, Hall and Patel (1985) observed that cowpea plants under high moisture regimes produced more pods per plant than those under deficient moisture.[37] also reported that limited moisture supply reduced number of pods per plant in groundnut.

Mean cowpea grains weight was not significantly (P < 0.05) affected by cowpea genotypes and weeding regimes, but was found to be significantly (P < 0.05) affected by planting density levels[table 13]. Based on varietal means, the improved cowpea variety[IT86D-721] had slightly higher mean grains weight of about 63.2g, than the local variety[Musia], which had mean grains weight of about 62.6g. Plots weeded once recorded the highest mean grains weight of about 65.0g, while plots weeded twice and where no weeding was done recorded the least mean grains weight of about 61.1kg and 62.6g respectively. Plots with higher planting density[456522 plant ha^{-1}] recorded the highest mean grains weight of about 75.1g, while plots with smaller plant densities[239130 and 152174 plant ha^{-1}] recorded the least mean grains weight of about 57.8g and 55.8g respectively[table 13]. The higher grains weight of cowpea recorded in plots weeded, compared with the lower grains weight recorded in un-weeded plots may have been due to the lower weed density in plots weeded.[46 and 35] found that 100-seed weight was not affected by plant population. However, result obtained in this study is in agreement with observations made by[25], as they found that the highest seed yield was obtained with higher plant density. The need to further investigate the effects of weeding regime and planting density on grains weight of cowpea is important for a better conclusion to be made on the yield potential of the two cultivars.

Table 10. Effects of cowpea genotypes, weeding regime and plant density on number of dry pods harvested

Variety	Weeding regime			Varietal means	Plant density			Varietal means
	W_0	W_1	W_2		P_1	P_2	P_3	
IT86D-721	6.24	6.16	5.75	6.05ns	4.19	6.30	7.65	6.05ns
Musia	5.53	5.89	5.03	5.49ns	3.90	5.35	7.20	5.49ns
Mean	5.89 ns	6.03 ns	5.39 ns		4.05**	5.83**	7.43**	
LSD (P <0.05)	3.260			LSD (P <0.05)	3.260			
CV%	34.1			CV%	34.1			

*** * = highly significant (P < 0.05); ns = Not significant (P > 0.05)**
W_0 = No-weeding, W_2= One-hoe weeding @ 3 weeks after sowing, W_3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P_1= 456,521.7391 plants ha^{-1}[50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1}[50cm X 30cm]

Table 11. Effects of cowpea genotypes, weeding regime and plant density on number of pods damaged

Variety	Weeding regime			Varietal means	Plant density			Varietal means
	W_0	W_1	W_2		P_1	P_2	P_3	
IT86D-721	3.20	3.18	2.17	2.85*	1.98	3.01	3.57	2.85*
Musia	2.14	2.15	1.85	2.05*	1.51	2.11	2.52	2.05*
Mean	2.67 ns	2.66 ns	2.01 ns		1.74*	2.56*	3.04*	
LSD (P <0.05)	2.145			LSD (P <0.05)	2.145			
CV%	52.8			CV%	52.8			

*** = significant (P < 0.05); ns = Not significant (P > 0.05).**
W_0 = No-weeding, W_2= One-hoe weeding @ 3 weeks after sowing, W_3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P_1= 456,521.7391 plants ha^{-1}[50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1}[50cm X 30cm]

Table 12. Effects of cowpea genotypes, weeding regime and plant density on number of pods undamaged

Variety	Weeding regime			Varietal means	Plant density			Varietal means
	W_0	W_1	W_2		P_1	P_2	P_3	
IT86D-721	3.09	3.31	3.46	3.28 ns	2.01	3.74	4.10	3.28 ns
Musia	3.40	3.74	3.07	3.40 ns	2.39	3.13	4.69	3.40 ns
Mean	3.24 ns	3.53 ns	3.27 ns		2.20**	3.44**	4.39**	
LSD (P <0.05)	2.043			LSD (P <0.05)	2.043			
CV%	36.8			CV%	36.8			

*** * = highly significant (P < 0.05); ns = Not significant (P > 0.05)**
W_0 = No-weeding, W_2= One-hoe weeding @ 3 weeks after sowing, W_3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P_1= 456,521.7391 plants ha^{-1}[50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1}[50cm X 30cm]

Table 13. Effects of cowpea genotypes, weeding regime and plant density on mean grains weight of cowpea

Variety	Weeding regime			Varietal means	Plant density			Varietal means
	W_0	W_1	W_2		P_1	P_2	P_3	
IT86D-721	64.9ns	60.0ns	64.6ns	63.2 ns	74.4	57.7	57.4	63.2ns
Musia	60.3ns	69.9ns	57.5ns	62.6 ns	75.7	57.9	54.2	62.6ns
Mean	62.6ns	65.0ns	61.1ns		75.1*	57.8*	55.8*	
LSD (P <0.05)	18.19			LSD (P <0.05)	18.19			
CV%	30.2			CV%	30.2			

*** = significant (P < 0.05); ns = Not significant (P > 0.05)**
W_0 = No-weeding, W_2= One-hoe weeding @ 3 weeks after sowing, W_3 = Two-hoe weeding twice @ 3 weeks after sowing and 6 weeks after sowing
P_1= 456,521.7391 plants ha^{-1}[50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1}[50cm X 30cm]

The cowpea fresh stover weight was significantly (P > 0.05) influenced by cowpea genotypes and plant density. The improved variety[IT86D-721] had a significantly (P > 0.05) higher fresh stover weight than the local variety [Musia] [Table 14]. Plots with lower plant density of [152174 plants ha^{-1}] had significantly (P > 0.05) lower fresh stover weight; while plots with higher plant density[456522 plants ha^{-1}] had significantly (P > 0.05) higher fresh stover weight. The fresh stover weight was not however significantly (P > 0.05) affected by weeding regime.

Table 14. Effects of cowpea genotypes and plant density on fresh weight of stover/fodder

Variety				Variety Mean
	P_1	P_2	P_3	
IT86D-721	574	404	399	459**
Musia	433	292	240	322**
Mean	504**	348**	320**	
LSD (P < 0.05)	117.8			
CV%	44.5			

*** * = Highly significant (P < 0.05)**
P_1= 456,521.7391 plants ha^{-1} [50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1} [50cm X 30cm]

As shown in table 15, cowpea dry stover weight was not significantly (P > 0.05) influenced by cowpea genotypes, but was significantly (P > 0.05) influenced by plant density levels. However, the improved variety[IT86D-721] had a higher dry stover weight than the local[Musia]. Plots with lower plant density[152174 plants ha^{-1}] had significantly (P > 0.05) lower dry stover weight; while plots with higher plant density[456522 plants ha^{-1}] had significantly (P > 0.05) higher dry stover weight.

Table 15. Effects of cowpea genotypes and plant density on dry weight of stover/fodder

Variety	Plant density			Mean
	P_1	P_2	P_3	
IT86D-721	133.8	106.5	96.7	112.3 ns
Musia	118.9	89.1	66.5	91.5 ns
Mean	126.4*	97.8*	81.6*	
LSD (P > 0.05)	31.60			
CV%	44.5			

*** = Significant (P < 0.05); ns = Not significant (P > 0.05).**
P_1= 456,521.7391 plants ha^{-1} [50cm X 10cm], P_2 = 239,130.4348 plants ha^{-1} [50cm X 20cm], P_3 = 152,173.913 plants ha^{-1} [50cm X 30cm]

4. Conclusions

Results of this study demonstrate the importance of weeding and planting spacing or density as major factors that significantly (P<0.05) contribute to low productivity of cowpea. Generally weeds infestations in the experimental plots were observed to be relatively high, thus justifying the reason for their significant impact on the agronomic traits, grains weight and stover/fodder weight of the two cowpea cultivars measured in this study. The reason for the difference in weed density and biomass between the two cowpea varieties could perhaps be attributed to the difference in genetic potential of the cultivars. It is clear from this study that weeds tend to increase in density, in plots that are un-weeded; compared with where weeding is done, irrespective of the frequency of weeding. Although plant density had no significant effect on weed density, it was however found that weed density decreased in plots with higher plant density.

It can also be concluded from this study that, the wider the space between plants stands and the lower planting density, the better the access to growth resources and hence the better the potential for increase in growth parameters. With no competition threat for moisture, nutrients, light, air, etc; plants that are well spaced have the potential to grow better; compared with where competition is high. This may explain the reason for the larger number of pods harvested in plots where plants were widely spaced than in plots where plants were clustered together. Even though weeding regime had no significant (P<0.05) effect on number of pods produced, the one-hand weeded plots (weeding at 3 weeks after planting) produced more pods than the un-weeded and two-hand weeded plots (weeding twice at 3 and 6 weeks after planting). Similarly, the un-weeded plots had more damaged pods than one-hand and two-hand weeded plots respectively, and vice versa. This implies that, in addition to moisture, nutrient condition in the soil, light; a weed-free condition is ideal for better plant growth, than in situations where these conditions are limited. The better plots are weeded, the more the expected number of pods produced, and the less the number of undamaged pods and grains. Based on the findings in this study, the following recommendations are made:

[i] It is obvious to note that hand/hoe weeding once and twice at 3 and 6 weeks after sowing is effective to control weeds, and thus is recommended for improving vegetative growth performance and grain yield of cowpea.

[ii] More studies need to be conducted to fully investigate the reason for the disparities between the weed densities and biomass between the different cowpea genotypes used in this trial. Laboratory analysis of plant extracts obtained from each cowpea variety could help identify the bioactive components of each cultivar. This will help in identifying the allelopathic potential of each plant material, which plays significant role in helping to make a definite conclusion.

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