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EFFECT OF PLANT POPULATION DENSITY ON GROWTH AND WEED SMOTHERING ABILITY OF COWPEA (*Vigna unguiculata* (L.) Walp.)

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Abstract
Akidi (cowpea), a landrace of *Vigna unguiculata*, was grown at densities of 30,121 (D1), 40,323 (D2), 50,000 (D3), 60,976 (D4), 80,645 (D5), and 0 (D6) plants/hectare in a randomized complete block design to assess the effect of intraspecific (between cowpeas) on its performance and weed smothering ability in the instance of utilizing it in intensive fallow management. At 10 weeks after sowing (WAS), the low-density plants (D1) were shorter (127.55 ± 1.84cm), produced highest stem diameter of 11.59 ± 0.86mm, and shoot dry weight/plant (12.46 ± 0.70g). The high-density cowpea treatment (D5) had the longest vines (197.93 ± 1.54cm) and relatively low shoot dry weight/plant (9.22 ± 0.64g). The D5 treatment was significantly better than other treatments in weed control and dry matter yield per unit area. *Tithonia diversifolia* and *Sida acuta* which are heliophytes were encountered in low-density treatments of D1 and D3, where the highest light intensities reached the soil.

Keywords: ***Akidi*, sown fallow, dry matter accumulation, weed management, growth, density**

Introduction

Weed management technology has advanced from hoe weeding and manual tillage, due to labour scarcity and high cost; a situation that has presented herbicides as the best control measures (Isaac *et al*., 2013). Chemical weed control has been the most common weed control technique in intensive farming. Increased weed resistance to herbicides and increased environmental and economic costs have led to a need for reduced herbicide use on farmlands. Organic farming systems are gaining popularity around the world as a result of these potential issues and increased public pressure on traditional agriculture (Weerarathne *et al*., 2017). Weed control, on the other hand, is widely acknowledged as the most significant production-related issue in organic farming systems and is thus one of the primary reasons why traditional farmers do not embrace organic farming (McErlich and Boydston, 2013). The use of a cover crops, and planting density manipulation, are all thought to be critical for improving crop competitiveness against weeds and preventing yield losses in crop plants (Kocira *et al*., 2020).

Increasing density of *Senna obtusifolia* used as sown fallow plant has previously been reported to suppress weeds (Awodoyin and Ogunyemi 2005) in organic systems; evidence for a suppressive effect of crop seeding rates above the norm has also been confirmed (Clark *et al*., 2017). Bulson *et al*. (1997) discovered that increasing the densities of wheat (*Triticum aestivum* L.) and field bean (*Vicia faba* L.) intercrops decreased weed biomass significantly. According to Arce *et al*. (2009), soybean seeding rates (24 – 42 seeds/m^2) were inversely related to weed biomass. Sangoi (2001) reported that when seeding rate is increased beyond optimum plant density, there are a number of side effects which are harmful to ear development and result in sterility. Increased seeding rates result in faster canopy closure, increased crop disturbance, and greater weed suppression, both of which result in higher yields (Nichols *et al*., 2015). Therefore, increased crop density as a cultural weed control method will enhance the use of cover crops for weed suppression. Vasilikiotis (2018) discovered that using a cover crop in conjunction with increasing crop plant density culminated in a mutual relationship that resulted in greater weed suppression than would have been expected from using either technique alone.

Limited information is available on herbicide-free weed management practices that provide adequate weed suppression while maintaining acceptable yields. Despite reports on the effect of cowpea as a living mulch on weed suppression, to the best of our knowledge, no study has investigated the effect of varying densities of *Akidi* used as living mulch on weed suppression. The objective of this study therefore, was to evaluate the effect of varying planting densities of *akidi* (used as living mulch) on growth and biomass yields of the cowpea and weed suppression ability in Ibadan, Nigeria.. The study varied the intensity of light that was received at the soil surface.

Materials and Methods

The study was carried out in the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan (Latitude 7°27`N; Longitude 3°53`E; Elevation 218m above sea level). The study was conducted from December 2014 to August 2016. Ibadan is located in a transitional rainforest-savanna region with a precipitation: evapotranspiration ratio of 1.0 (Awodoyin and Olubode, 2009). Ibadan is situated in the rainforest Guineo-Congolian: drier type with a mosaic flora that is made up of rainforest lowlands and secondary grasslands (White, 1983). The soils are underlain by rocks of pre-cambrain basement complex, characterized by deep and intensely weathered pedons with few remaining weatherable mineral materials, and have low clay content which is made of kaolinite (Akindele, 2011). This area is characterized by bimodal yearly precipitation with peaks in July and September, with yearly precipitation as 1200 - 1500mm. The wet period runs from April through October, relative humidity is moderate (60–80%), and average temperature between 27 °C – 32°C (Adelekan and Gbadegesin, 2005). The seeds of *Akidi*, a landrace of *Vigna unguiculata* (L.) Walp. were obtained from Agricultural Development Program (ADP) in Ivo Local Government Area, Ebonyi State, Nigeria. The planting densities studied were D1: 30,121 plants per hectare obtained by sowing at spacing 0.83m × 0.40m, D2: 40,323 plants per hectare (0.62m × 0.40m), D3: 50,000 plants per hectare (0.50m × 0.40m), D4: 60,976 plants per hectare (0.41m × 0.4 m), D5:80,645 plants per hectare (0.31m × 0.40m) and D6: check plot (Control) which was not planted with *Akidi*. The trial which lasted for 10 weeks was set up in a randomized complete block design with four replications. Each plot was 1.20m × 1.40m in dimension. The distance between contiguous plots and contiguous blocks was 50cm, each. The field was under fallow with *Tithonia diversifolia,* manually cleared and cultivated with a hoe. The soil of the study site was loamy sand, with low organic carbon and nitrogen contents (Table 1). The plots were marked with 40cm inter-row spacing but with varying intra-row spacing as indicated earlier to obtain the various densities. The seeds were sown two seeds per hole at 2cm depth. The plot with zero plantings served as the control plot to compare the weed control efficiency of the plant at the different densities. At two weeks after planting (WAP), germinated seeds were thinned to one plant per stand. At harvest (10 WAP), five plants, randomly selected in each plot, were assessed for the following parameters:

a)Vine length: measured with a meter rule in centimeter (cm).

b)Stem diameter at soil surface: measured with a vernier caliper in millimeters (mm).

c).Dry matter accumulation: the five selected plants were clipped with a secateurs at the soil surface and dried at 80oC for 48 hours in a Gallenkemp oven. The oven-dried materials were weighed with a top-loading Mettler balance (P1210) to monitor the effect of density on above-ground (shoot) dry matter accumulation. Weed Control Efficiency (WCE) of the plant at various densities was assessed as follows in Table 1.

Table 1: Soil physicochemical characteristics of the study site

Properties	Values
pH (H_2O)	6.2
Organic Carbon (%)	16.0
Total N (g/kg)	2.0
Available P (mg/kg)	15.0
Exchangeable K (cmol/kg)	0.2
Sand (g/kg)	783.0
Silt (g/kg)	145.0
Clay (g/kg)	72.0

a)Weed Dry Matter: two 25cm × 25cm quadrats were randomly laid within each plot at 10 WAP. All weeds that rooted within each quadrat were clipped at the soil surface with secateurs. The weed samples were dried in the oven at 80°C for 48 hours and weighed to determine the dry matter.

b)Weed Spectrum and Frequency: all weeds that rooted within each quadrat were identified using a flora handbook by Akobundu and Agyakwa (1987).

Data Analysis

The data from the four blocks were pooled by treatment to eight (8) quadrats per treatment. For each treatment, the percentage frequency of each weed species was estimated based on the number of quadrats that contained the species out of the total 8 quadrats.

$$\% \text{ Frequency } = \frac{\text{Number of quadrats with species}}{\text{Total number of quadrats per treatment (8)}} \text{ x } 100$$

The treatments were compared with analysis of variance (ANOVA) and means separated with Least Significant Difference (LSD) at a 5% level of probability. The Paleontological Statistics and Software Package for Education and Data Analysis (PAST) by Hammer *et al.* (2001) was used to interpret the collected data.

Results and Discussion

Vegetative growth – Vine Length and Stem Diameter

The effect of planting density of *akidi* on some growth parameters is presented in Table 2. The vine increased with increasing density across the two trials. The longest vines (198cm and 201cm) were obtained at a population density of 80,645plants/ha (D5) in both studies.

There was an inverse relationship between planting density and stem diameter. Diameter reduced with increasing planting density. The difference in stem diameter between D1 and D3 was not significant (P = 0.05) but was larger than D4 and D5 which were similar. The largest stem was 12mm, while the smallest was 7mm in the first trial and 12mm and 8mm, respectively, in the second trial.

Shoot Dry Matter Yield of Vigna unguiculata

The shoot dry weight/plant and weed dry weight/m^2 decreased with increasing planting density across trials. Weed dry weight was least in D5; 9.18g in the first trial and 9.02g in the second trial. There were no significant variations in this parameter between the treatments of D2 and D4 across the two trials. The shoot dry weight/m^2 increased with increasing planting density of *Vigna unguiculata*. The highest value of 73.76 ± 1.27g and 74.24 ± 1.05g were recorded in the highest planting density (D5) in the first and second trials, respectively (Table 3).

Weed biomass and spectrum

Weed population increased with reduction in plant populations; the highest reduction was by 81% at the highest planting density (D5) and the least by 64% at the lowest planting density in the first trial. The trend was similar in the second trial (Table 4). A total of 27 plant species from 13 families was enumerated in the first trial. *Tridax procumbens* dominated with the highest Relative importance value (RIV) of 29.47% (D1); 30.46% (D2); 25.71% (D3); 25.89% (D4); 27.11% (D5) and 26.48% (D6) in the first trial (Table 5). Species with low RIV were *Corchorus olitorius, Crotalaria retusa, Desmodium scorpiurus* and *Sida acuta* with RIV of 2.10% each in D1 (Table 5). A total of 28 plant species from 14 families was enumerated in the second trial. *Tridax procumbens* dominated with the highest RIV of 44.54%.

Planting of *Vigna unguiculata* at 80,645 plants per hectare (D5) produced significantly longer vines than the other tested densities. At high planting density (D5), the amount of light that reached individual plants was reduced, due to shading which caused etiolation, a situation where plants grew rapidly to reach the light. It is a negative response to reduced light stress, a mechanism described as helioplastic response of shade-intolerant plants to light stress. The result may imply that *Vigna unguiculata* can only withstand moderate shade which corroborates research reports that shading effect on trailing legume is responsible for long vines, reduced specific leaf weight (SLW), and increased leaf area by unit weight (Tardieu, 2013). With the imposition of reduced light, much of the nutrients allotted to growth were probably alloted to cell elongation which resulted in enhanced vine length at the expense of improvements in stem diameter. The strong inverse relationship between the shoot biomass per plant and planting density indicates an intense intra-specific competition for space. This competition is attributed to the imposed high density that resulted in reduced space and resources. Being of the same species, the plants had similar ecological requirements and occupied the same niche (Pocheville, 2015). Thus, the low dry matter yield per plant in the high-density plots (D5) could have been a result of intra-specific competition. According to Liebman and Davis (2009), when two or more crops grow simultaneously, each constituent crop should enjoy sufficient space to fully exploit cooperation between the crops. The vast amounts of plants per unit area accounted for the low shoot dry matter yield per plant in the high-density plots (D5).

The high weed biomass reduction effect of D5 compared with the control observed in this study indicates that *V. unguiculata* has the potential to serve as a ′smother plant`, capable of suppressing the growth of weed seedlings at a planting density range of 50,000 - 80,645 plants per hectare. The superior planting density in this context is at 80,645 plants per hectare. The *V. unguiculata* at varying densities was able to shade and starve weeds of solar radiation, which resulted in a marked reduction in weeds' photosynthetic ability and led to low biomass production. According to a report by Dada (2010), cowpea-based mixtures were found to starve weeds of solar radiation. Awodoyin and Ogunyemi (2005) in their assessment of the effect of proximity of neighbouring plants on plant performance and weed smothering ability of *Senna obtusifolia* reported a strong negative correlation (r = -0.93) effect between stocking density and weed biomass; and that the highest density (200 plants/m^2) was significantly better than other treatments in weed control. The report is similar to the results of this study and can be ascribed to better land coverage in the high planting density treatment (D5) of *Vigna unguiculata*.

Conclusion

In this study, the proximity among neighbours of *akidi* at a density of 30,121 – 80,645 plants per hectare resulted in a dense coverage that aided effective weed smothering. This suggests that the *akidi* is a good sown fallow plant. The similarities of tested densities as regards biomass production indicates that dense spacing for rapid canopy closure prevents the germination of weed seeds in the soil seed bank and smothered weed seedlings does not reduce herbage yield for green manuring and mulching. The fact that *Tithonia diversifolia* was only present at low planting densities (D1 and D3) suggests that the weed was effectively controlled by high densities of *akidi* (*Vigna unguiculata*).

Table 2: Effects of *Vigna unguiculata*(*akidi*) planting density on its vegetative growth at 10 weeks after Sowing (Values are means ± S.E; n = 4)

Density (Plant/hectare)	Vine Length cm/plant	Stem diameter (mm)
First trial		
D1 (30,121)	127.55 ± 1.84	11.59 ± 0.86
D2 (40,323)	146.48 ± 1.23	10.11 ± 1.03
D3 (50,000)	158.00 ± 2.27	9.92 ± 0.91
D4 (60,976)	172.73 ± 1.43	8.90 ± 0.75
D5 (80,645)	197.93 ± 1.54	7.08 ± 0.62
D6 (Control)	-	-
LSD (0.05)	4.44	2.21
Second trial		
D1 (30,121)	130.25 ± 2.18	12.10 ± 0.97
D2 (40,323)	149.08 ± 1.73	11.79 ± 0.89
D3 (50,000)	162.96 ± 1.40	10.07 ± 0.95
D4 (60,976)	173.87 ± 1.42	8.21 ± 0.90
D5 (80,645)	201.47 ± 1.18	7.93 ± 0.88
D6 (Control)	-	-
LSD (0.05)	4.23	2.40

Table 3: Effect of planting density on dry matter accumulation of *Vigna unguiculata* at 10 weeks after sowing (Values are means ± S.E; n = 4)

Density (plant/hectare)	Shoot Dry Weight/plant (g)	Shoot Dry Weight (g) / m^2
First trial		
D1 (30,121)	12.46 ± 0.70	37.38 ± 1.08
D2 (40,323)	11.50 ± 1.02	46.00 ± 1.11
D3 (50,000)	10.15 ± 0.82	60.90 ± 1.67
D4 (60,976)	9.96 ± 0.81	69.72 ± 1.10
D5 (80,645)	9.22 ± 0.64	73.76 ± 1.27
D6 (Control)	-	-
LSD (0.05)	2.11	3.31
Second trial		
D1 (30,121)	12.74 ± 1.14	38.22 ± 1.17
D2 (40,323)	11.72 ± 0.91	46.88 ± 1.02
D3 (50,000)	10.65 ± 0.90	63.90 ± 1.19
D4 (60,976)	10.12 ± 1.06	70.84 ± 0.84
D5 (80,645)	9.28 ± 0.65	74.24 ± 1.05
D6 (Control)	-	-
LSD (0.05)	2.46	2.77

Table 4: Effect of plantig density on dry matter accumulation of weed plants at 10 weeks after sowing. (Values are means ± S.E; n = 4)

Density (plant/hectare)	Weed Dry Weight (g)	Weed Reduction (%)
First trial		
D1 (30,121)	17.34 ± 1.04	64.36
D2 (40,323)	14.82 ± 0.91	69.54
D3 (50,000)	12.34 ± 1.03	74.64
D4 (60,976)	11.39 ± 0.87	76.59
D5 (80,645)	9.18 ± 0.86	81.13
D6 (Control)	48.66 ± 0.87	-
LSD (0.05)	2.40	
Second trial		
D1 (30,121)	28.23 ± 1.24	57.52
D2 (40,323)	16.52 ± 0.93	75.14
D3 (50,000)	15.47 ± 1.08	76.72
D4 (60,976)	14.75 ± 1.17	77.81
D5 (80,645)	9.02 ± 1.06	86.42
D6 (Control)	66.46 ± 0.93	-
LSD (0.05)	2.77	

Table 5: Relative importance value of weed species encountered on plots of *Vigna unguiculata* planted at varying population densities in Ibadan, Nigeria (n = 8) - First Trial

S/No	Species Name	Family	D1	D2	D3	D4	D5	D6
1	*Ageratum conyzoides* Linn.	Asteraceae	11.96	16.39	15.76	17.67	15.48	15.95
2	*Amaranthus cruentus* Linn.	Amaranthaceae	-	-	2.29	-	-	-
3	*Boerhavia diffusa* Linn.	Nyctaginaceae	11.86	7.35	2.88	11.75	7.24	7.59
4	*Brachiaria deflexa* (Schumach) Robyns.	Poaceae	12.28	12.14	13.35	12.92	11.09	22.57
5	*Corchorus olitorius* Linn.	Malvaceae	2.10	-	2.29	-	-	-
6	*Crotalaria retusa* Linn.	Fabaceae	2.10	-	-	2.44	2.41	2.71
7	*Desmodium scorpiurus* (Swartz) Desvaux	Fabaceae	2.10	2.15	2.59	2.11	-	-
8	*Euphorbia heterophylla* Linn.	Euphorbiaceae	7.87	7.65	5.47	4.89	6.27	8.99
9	*Euphorbia hirta* Linn.	Euphorbiaceae	6.09	8.55	5.47	6.20	6.76	4.01
10	*Euphorbia hyssopifolia* Linn.	Euphorbiaceae	2.73	2.45	-	2.11	-	-
11	*Eleusine indica* (L.) Gaertn.	Poaceae	-	3.05	-	2.44	-	-
12	*Eragrostis atrovirens* (Desfontaines) Steudel	Poaceae	-	-	3.76	-	3.38	-
13	*Eragrostis tenella* (L.) P. Beauv.ex Roem. & Schult.	Poaceae	2.42	2.45	3.76	-	-	-
14	*Mitracarpa villosus* (Sw.) DC.	Rubiaceae	-	-	-	-	2.83	-
15	*Phyllanthus amarus* Schumach	Phyllanthaceae	4.51	2.45	-	2.11	2.41	3.14
16	*Portulaca oleracea* Linn.	Portulacaceae	-	-	-	2.11	-	3.14
17	*Rhaponticum repens* (L.) Hidalgo	Poaceae	-	-	2.59	-	-	-
18	*Setaria longiseta* P.Beauv.	Poaceae	-	-	2.29	-	-	-
19	*Sesbania pachycarpa* sensu auct.	Fabaceae	-	-	2.29	-	-	2.71
20	*Sida acuta* Burm F.	Malvaceae	2.10	-	-	-	-	-
21	*Solanum nigrum* Linn.	Solanaceae	-	-	-	2.44	-	-
22	*Spigelia anthelmia* Linn.	Loganiaceae	2.41	-	-	2.44	3.38	-
23	*Stachytarpheta cayennensis* (Richard) Vahl.	Verbenaceae	-	2.15	2.29	-	-	2.71
24	*Talinum fruticosum* (L.) Juss.	Talinaceae	-	-	4.59	-	-	-
25	*Tithonia diversifolia* (Hemsl.) A. Gray.	Asteraceae	-	-	3.76	-	-	-
26	*Tridax procumbens* Linn.	Asteraceae	29.47	30.46	25.71	25.89	27.11	26.48
27	*Vigna unguiculata* (L.) Walp.	Fabaceae	-	-	2.59	2.44	11.58	-

Note = D1: Vigna unguiculata (30,121 plant/ hectare); D2: Vigna unguiculata (40,323 plant/hectare); D3:Vigna unguiculata (50,000 plant/hectare); D4:Vigna unguiculata (60,976 plant/hectare); D5:Vigna unguiculata (80,645 plant/hectare); D6:check plot (control. (D1); 35.94% (D2); 29.94% (D3); 39.40% (D4); 30.57% (D5) and 48.12% (D6) (Table 6). Species with low RIVs were Corchorus olitorius (D2) and Vigna unguiculata (D2) with RIV of 1.66% each for the second trial experiment (Table 6)

Table 6: Relative importance value of weed species encountered on the plots of *Vigna unguiculata* planted at varying population density (n = 8) – Second Trial

S/No	Species Name	Family	D1	D2	D3	D4	D5	D6
1	*Ageratum conyzoides* Linn.	Asteraceae	8.16	9.06	12.60	13.81	13.64	10.48
2	*Amaranthus cruentus* Linn.	Amaranthaceae	-	3.31	2.32	-	-	-
3	*Boerhavia diffusa* Linn.	Nyctaginaceae	-	5.65	5.11	23.75	7.75	2.10
4	*Brachiaria lata* (Schumach.) C.E Hubbard	Poaceae	-	-	-	-	6.64	2.10
5	*Brachiaria deflexa* (Schumach) Robyns	Poaceae	5.37	8.90	13.77	26.42	5.91	3.32
6	*Corchorus olitorius* Linn.	Malvaceae	1.99	1.66	2.09	20.69	-	2.10
7	*Commelina benghalensis* Linn.	Commelinaceae	4.57	-	-	-	-	-
8	*Crotalaria retusa* Linn.	Fabaceae	-	1.88	-	5.07	5.17	-
9	*Desmodium scorpiurus* (Swartz) Desvaux	Fabaceae	-	-	-	20.69	-	-
10	*Euphorbia heterophylla*	Euphorbiaceae	4.57	5.42	9.29	4.27	5.54	4.51
11	*Euphorbia hirta*	Euphorbiaceae	4.17	5.88	4.88	21.84	2.95	4.71
12	*Euphorbia hyssopifolia* Linn.	Euphorbiaceae	-	-	-	2.33	-	-
13	*Eleusine indica* Linn.	Poaceae	-	-	-	1.94	-	2.20
14	*Eragrostis atrovirens* (Desfontaines) Steudel	Poaceae	-	-	-	-	2.59	-
15	*Eragrostis tenella* (L.) P. Beauv.ex Roem. & Schult.	Poaceae	-	-	-	-	-	2.10
16	*Mitracarpus villosus* (Sw.) DC.	Rubiaceae	4.17	-	-	-	2.95	-
17	*Momordica charantia* Linn.	Cucurbitaceae	-	3.31	-	-	-	-
18	*Phyllanthus amarus* Schumach	Phyllanthaceae	-	-	-	21.46	2.22	2.31
19	*Portulaca oleracea* Linn.	Portulacaceae	-	-	-	2.33	-	2.31
20	*Rhaponticum repens* (L.) Hidalgo	Poaceae	9.94	10.49	9.78	7.40	2.22	4.92
21	*Sesbania pachycarpa* sensu auct.	Fabaceae	4.17	3.54	2.09	1.94	-	4.40
22	*Solanum nigrum* Linn.	Solanaceae	-	-	-	21.08	-	-
23	*Spigelia anthelmia* Linn.	Loganiaceae	-	-	-	3.89	4.81	2.20
24	*Stachytarpheta cayennensis*	Verbenaceae	-	-	2.32	-	-	2.10
25	*Talinum fruticosum* (L.) Juss.	Talinaceae	4.17	3.31	2.32	20.69	-	-
26	*Tithonia diversifolia* (Hemsl.) A. Gray.	Asteraceae	2.19	-	3.50	-	-	-
27	*Tridax procu8mbens* Linn.	Asteraceae	44.54	35.94	29.94	39.40	30.57	48.12
28	*Vigna unguiculata* (L.) Walp.	Fabaceae	1.99	1.66	-	20.69	7.03	-

Note = D1: Vigna unguiculata (30,121 plant/ hectare); D2: Vigna unguiculata (40,323 plant/hectare); D3: Vigna unguiculata (50,000 plant/hectare); D4: Vigna unguiculata (60,976 plant/hectare); D5: Vigna unguiculata (80,645 plant/hectare); D6: check plot (control

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