*NIGER AGRIC. J. 36 (2005)71-79*

# THE EFFECT OF POPULATION DENSITY OF FOUR VEGETABLE COWPEA VARIETIES ON WEED GROWTH AND OCCURRENCE ON AN ULTISOL

**Ekeleme, F. and Nwofia G. E.**
Michael Okpara University of Agriculture, Umudike
P.M.B. 7267, Umuahia, Abia State

## ABSTRACT

A 2-year field study was conducted at the Research Farm of Michael Okpara University of Agriculture, Umudike to investigate the effect of planting density of four vegetable cowpeas on weed interference. Akidiani (prostrate), Akidienu (climbing), IT86F-2014-1 (erect), and IT81D-1228-14 (semibushy) were planted at densities of 5, 7, 10, and 20 plants $m^{-2}$. The magnitude of weed suppression varied between the cowpea varieties. The prostrate and semi-bushy varieties had the lowest weed density and dry matter. Weed density was lower in the prostate variety by 54 and 67% and in the semi-bushy variety by 42 and 57% compared with the climbing and erect varieties, respectively. On average, weed density in the prostrate variety decreased from 186 to 61 plants $m^{-2}$ and from 229 to 78 plants $m^{-2}$ in the semi-bushy variety after 2 years of continuous cultivation. Averaged over cowpea variety, weed density and dry matter was lowest when the cowpea was seeded at 20 plants $m^{-2}$ at 50 cm x 10 cm spacing. *Mimosa invisa* accounted for >30% of the species abundance in each of the varieties. $N_2$ diversity, a measure of very abundant species was 5.2, 5.3, 4.4 and 4.2 in plots seeded to the erect, climbing, prostrate and semi-bushy varieties, respectively. The five and four very abundant species in the erect and climbing and in the prostrate and semi-bushy varieties, respectively contributed >70% of the species abundance. The results suggest that the prostrate and the semi-bushy varieties have potentials as cover crop in weed management at high seeding rates.

## INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp) is an important food crop in West and Central Africa but until recently its cultivation in Nigeria was limited to the Sahel, Guinea and Derived savannas. In the humid forest fringes (HFF) the most widely grown varieties are the vegetable types whose immature succulent pods are eaten by humans. In the HFF and in the traditional cropping systems vegetable cowpea are mainly grown as companion crops in yam, maize, cassava and in mixtures of these crops. In this type of cropping system, the vegetable cowpea is planted at wide and random spacing on mounds or ridges with no definite row arrangement and hence no population density. In recent years, with increasing emphasis on plant protein in human diet in preference to animal protein the cultivation of vegetable cowpea has risen steadily in this region in response to increase in demand. It is reasoned that population studies integrated into the current management practices in the production of this crop would improve the overall production of the crop.

Weed competition and insect pests constitute the major constraints to the production of vegetable cowpea. Currently farmers manage weeds in this crop by hoe weeding and hand pulling. This method is labour intensive and often not appropriate during the flowering stage as farmers often delay weeding till this stage. Chemical control measure such as the use of herbicides is not a viable alternative since most small-scale farmers lack the financial resource base as well as the knowledge and capacity needed for effective use of herbicides. This fact is confounded by public concern about the effects of herbicides on the environment. Integrated weed management has therefore been suggested as viable option for small-scale crop production in the Nigeria (Ekeleme *et al.*, 2003). For vegetable cowpea production a possible approach would be to make the crop more competitive than the weed through the modification of the spatial arrangement and the relative plant population densities per unit area of land. Hume (1985) and O' Donovan (1994) reported that crop density had major effect on crop/weed interactions. Blumenthal and Ison (1994) noted plant population density as major determinant of agronomic success in annual crops in the sense that it determines total dry matter yield (Fukai and Silsbury, 1978). Japtap *et al.*, (1998) also showed that optimum plant density is important for maximum biological yield of crops.

In humid forest agro-ecology no work has been reported that investigated interactions between vegetable cowpea plant density and planting space on weed growth. However, some literature exists on the relationship between seeding rate/plant spacing and yield and yield components of some cowpea varieties (Haizel, 1972) but little is known of how cowpea population density and planting spacing impact on weeds. The objective of this study was to investigate the effect of vegetable cowpea density on weed growth and occurrence of natural weed population.

## MATERIALS AND METHODS

This study was carried out at the Research Farm of Michael Okpara University of Agriculture (05° 29' N, 07° 33' E), Umudike in 2002 and 2003 cropping seasons. Soil type was sandy clay loam with pH 4.8, 1.9% organic matter, 0.056% total nitrogen, and 27 ppm phosphorus. The soil was disc-ploughed and harrowed on 16 April, 2002 and 18 April, 2003.

The experiment was set up as a split plot in a randomized complete block design replicated three times. Four vegetable cowpea varieties consisting of two local (cv Akidiani [prostrate], Akidienu [climbing], and two improved varieties (IT86F-2014-1 [erect], and IT81D-128-14 [semibushy] constituted the main plot. Cowpea population densities of 5, 7, 10, and 20 plants $m^{-2}$ corresponding to 50,000, 67,000, 100,000 and 200,000 plants $ha^{-1}$ seeded at an inter-row spacing of 50 cm and intra-row spacing of 40, 30, 20, and 10 cm, respectively were the subplot treatment. Subplot size was 3 x 3 m with 1 m alley between main plots and replicates. Two cowpea seeds were sown per hill on the flat on 18 April 2002 and on 20 April 2003 and later thinned to one plant per hill at two weeks after planting (WAP) in both years. Insect pests at flowering and pod formation were controlled with Cypermetherin EC at 100 ml in 20 L of water. Each plot was hoe weeded twice at 4 and 8 WAP. Weed density and dry matter were collected at 4 and 8 WAP before hoe weeding. Weed density and weed samples for dry matter were taken from two 50 x 50 cm quadrats along a diagonal transect in each plot. In each quadrat weeds were identified and counted by species. Counted weed species were clipped at ground level and bulked for each plot to form a sample. Weed samples were oven dried at 80 °C for 48 hours for dry matter determination.

Cowpea leaf number, length and width (taken at the broadest width of the leaflet) were measured at 7 WAP and used to compute leaf area according to Osei-Yaboah et al. (1983) as follows:

$$Y = [2.325lw]n$$

where Y = cowpea leaf area, $l$ = cowpea leaf length, $w$ = cowpea width and $n$ = cowpea leaf number. Cowpea leaf area index (LAI) was computed as:

$$LAI = \left(\frac{T_{la}}{I_{tra} - I_{ter}}\right)$$

where $T_{la}$ = total leaf area per plant, $I_{tra}$ = intra-row spacing and $I_{ter}$ = inter-row spacing of each plant.

Weed density and dry mater data were subjected to analysis of variance using the mixed model procedures (PROC MIXED) in SAS (Little *et al.*, 1996). In the model, replicates were random factors whereas cowpea variety and cowpea population density were fixed effects. Means were separated using the standard error of the difference. $N_2$ diversity was computed for each main plot using CANOCO 3.1 (Ter Braak, 1990). $N_2$ diversity is the number of very bundant species in a given site (Hill, 1973). This was calculated as:

$$N_2 = \left(\frac{1}{\lambda}\right)$$

Where $\lambda$ = Simpson's index defined as $\sum_{i=1}^{s} p_i^2$

Where $Pi$ is the proportional abundance of the *i*th species. $N_2$ diversity was used in this study because it is more interpretable than other diversity indices and has the appeal of being in units of species numbers (Ludwig and main plot was drawn using the software CanoDraw (Smilauer, 1992).

## RESULTS AND DISCUSSION

### *Weed density*

There was no difference in weed density between the cowpea varieties at 4 ($P$ = 0.3964) and at 8 ($P$ = 0.9719) weeks after planting (WAP) in 2002 but a significant difference ($P$ < 0.0001) in weed density between the cowpea varieties was observed in 2003 (Table 1). In 2003, Akidiani (a prostrate variety) and IT81D-128-14 (a semi-bushy variety) had the lowest weed density. Weed density was lower in the prostate variety by 54 and 67% and in the semi-bushy variety by 42 and 57% compared with Akidienu (a climbing variety) and IT86F-2014-1 (an erect variety), respectively. In general, repeating

Table 1: Effect of cowpea variety and population density on weed density at 4 and 8 weeks after planting

| | 2000 | | 2003 |
|---|---|---|---|
| Treatment | 4WAP | SWAP | SWAP |
| | Number $m^{-2}$ | | |
| **Cowpea variety** | | | |
| Akidiani | 186 | 158 | 61 |
| Akidienu | 244 | 157 | 134 |
| IT86F-2014-1 | 251 | 163 | 184 |
| IT81D-128-14 | 229 | 164 | 78 |
| S.E.D (±) | 27.8 | 12.4 | 15.2 |
| **Cowpea density** | | | |
| 5 plants $m^{-2}$ | 217 | 167 | 97 |
| 7 plants $m^{-2}$ | 246 | 149 | 123 |
| 10 plants $m^{-2}$ | 127 | 162 | 117 |
| 20 plants $m^{-2}$ | 155 | 164 | 121 |
| S.E.D (±) | 24.4 | 11.9 | 14.7 |

[1]S.E.D = Standard error of the difference between two meansg

Table 2: Effect of the interaction of cowpea variety and population density on weed density at 8 weeks after planting

| Cowpea variety | Cowpea density (plants/ $m^2$) | | | |
|---|---|---|---|---|
| | 5 | 7 | 10 | 20 |
| | number $m^{-2}$ | | | |
| 2002 | | | | |
| Akidiani | 193 | 128 | 117 | 194 |
| Akidienu | 169 | 188 | 174 | 95 |
| IT86F-2014-1 | 121 | 149 | 151 | 230 |
| IT8ID-128-14 | 171 | 181 | 155 | 147 |
| S.E.D (±) | | 24.9 | | |
| 2003 | | | | |
| Akidiani | 66 | 49 | 77 | 52 |
| Akidienu | 165 | 181 | 99 | 90 |
| IT86F-2014-1 | 127 | 164 | 241 | 203 |
| IT8ID-128-14 | 126 | 73 | 73 | 41 |
| S.E.D (±) | | 30.4 | | |

[1]S.E.D = Standard error of the difference between two means

the experiment on the same plot for two years lead to a reduction of 26-67% in weed density across all the varieties. On the average, weed density in the prostrate variety decreased from 186 to 61 plants $m^{-2}$ and from 229 to 78 plants $m^{-2}$ in the semi-bushy variety. Averaged over cowpea variety, weed density was lowest when the cowpea was seeded at 20 plants $m^{-2}$ at 50 cm x 10 cm spacing.

The relationship between cowpea variety and seed density was variable. Cowpea variety interacted with the density significantly in both years ($P < 0.05$) at 8 WAP (Table 2). For example, weed density was lowest in the semi-bushy variety at 20 plants $m^{-2}$ at 50 cm x 10 cm spacing in both years compared with the other densities.This trend may be attributed to early and better ground cover at this density. Leaf area index for this variety measured at 7 WAP was 6.1 in 2002 and 4.7 in 2003 at seeding rate of 20 plants $m^{-2}$ at 50 cm x 10 cm spacing compared with 1.6 and 1.2 at seeding rate of 7 plants $m^{-2}$ at 50 cm x 30 cm spacing in 2002 and 2003, respectively (Table 3 & 4). O'Donovan, (1994) found that *Brassica rapa*, an oil seed reduced the competitive effects of weeds when the seeding rate was increased from low density to a higher density. In wheat, barley and soybean, high crop densities have been

**Table 3: Effect of cowpea population density on leaf area index at 7 weeks after planting in 2002.**

| Cowpea variety | Cowpea density (plants $m^{-2}$) | | | | |
|---|---|---|---|---|---|
| | 5 | 7 | 10 | 20 | Mean |
| | number $m^{-2}$ | | | | |
| Akidiani | 1.13 | 1.77 | 2.28 | 6.22 | 2.85 |
| Akidienu | 1.61 | 2.26 | 1.16 | 2.21 | 1.81 |
| IT86F-2014-1 | 1.33 | 1.20 | 2.21 | 2.57 | 1.83 |
| IT8ID-128-14 | 1.08 | 1.61 | 5.12 | 6.03 | 3.46 |
| Mean | 1.29 | 1.71 | 2.69 | 4.26 | |
| S.E.D (±) cowpea variety | | | 0.34 | | |
| S.E.D (±) cowpea density | | | 0.36 | | |
| S.E.D (±) variety x density | | | 0.68 | | |

[1]S.E.D = Standard error of the difference between two means

Table 4: Effect of cowpea population density on leaf area index at 7 weeks after planting in 2003.

| Cowpea variety | Cowpea density (plants $m^{-2}$) | | | | |
|---|---|---|---|---|---|
| | 5 | 7 | 10 | 20 | Mean |
| | number $m^{-2}$ | | | | |
| Akidiani | 1.41 | 1.70 | 1.84 | 5.78 | 2.68 |
| Akidienu | 1.04 | 1.63 | 1.64 | 2.97 | 1.82 |
| IT86F-2014-1 | 0.90 | 1.06 | 1.64 | 2.04 | 1.41 |
| IT8ID-128-14 | 0.84 | 1.17 | 3.37 | 4.67 | 2.5 |
| Mean | 1.04 | 1.39 | 2.12 | 3.86 | |
| S.E.D (±) cowpea variety | | | 0.32 | | |
| S.E.D (±) cowpea density | | | 0.33 | | |
| S.E.D (±) variety x density | | | 0.63 | | |

[1]S.E.D = Standard error of the difference between two means

**Table 3: Effect of cowpea population density on leaf area index at 7 weeks after planting in 2002.**

| Cowpea variety | Cowpea density (plants m$^{-2}$) | | | | |
|---|---|---|---|---|---|
| | 5 | 7 | 10 | 20 | Mean |
| | number m$^{-2}$ | | | | |
| Akidiani | 1.13 | 1.77 | 2.28 | 6.22 | 2.85 |
| Akidienu | 1.61 | 2.26 | 1.16 | 2.21 | 1.81 |
| IT86F-2014-1 | 1.33 | 1.20 | 2.21 | 2.57 | 1.83 |
| IT8ID-128-14 | 1.08 | 1.61 | 5.12 | 6.03 | 3.46 |
| Mean | 1.29 | 1.71 | 2.69 | 4.26 | |
| S.E.D (±) cowpea variety | | | 0.34 | | |
| S.E.D (±) cowpea density | | | 0.36 | | |
| S.E.D (±) variety x density | | | 0.68 | | |

[1]S.E.D = Standard error of the difference between two means

Table 4: Effect of cowpea population density on leaf area index at 7 weeks after planting in 2003.

| Cowpea variety | Cowpea density (plants m$^{-2}$) | | | | |
|---|---|---|---|---|---|
| | 5 | 7 | 10 | 20 | Mean |
| | number m$^{-2}$ | | | | |
| Akidiani | 1.41 | 1.70 | 1.84 | 5.78 | 2.68 |
| Akidienu | 1.04 | 1.63 | 1.64 | 2.97 | 1.82 |
| IT86F-2014-1 | 0.90 | 1.06 | 1.64 | 2.04 | 1.41 |
| IT8ID-128-14 | 0.84 | 1.17 | 3.37 | 4.67 | 2.5 |
| Mean | 1.04 | 1.39 | 2.12 | 3.86 | |
| S.E.D (±) cowpea variety | | | 0.32 | | |
| S.E.D (±) cowpea density | | | 0.33 | | |
| S.E.D (±) variety x density | | | 0.63 | | |

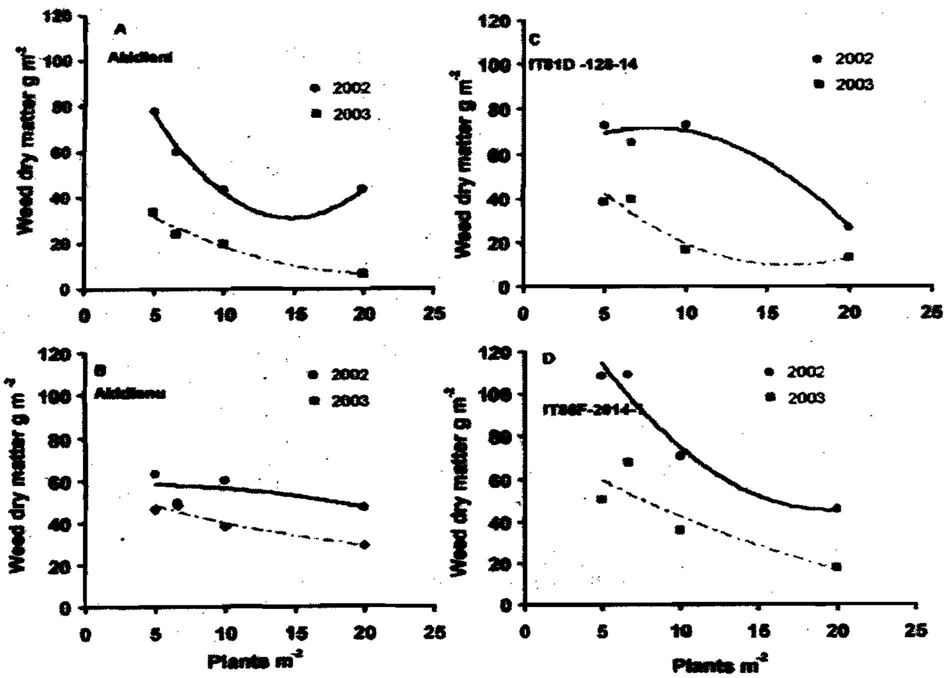
[1]S.E.D = Standard error of the difference between two means

shown to reduce weed growth and improve crop yield (Orwick and Schreiber, 1979, Carlson *et al*., 1985, Cudney *et al*., 1989, Barton *et al*., 1992,). In the erect variety, weed density was lowest at seeding rate of 5 plants $m^{-2}$ at 50 cm x 40 cm spacing. In 2002, weed density in plots seeded to the prostrate variety was lowest in plots with seed density of 10 plants $m^{-2}$ at 50 cm x 20 cm spacing. The trend in 2002 for the prostrate variety was not consistent with the observation in 2003, probably due to patches of die-back observed in 2003 plots.

### *Weed dry matter*

Weed dry matter was significantly different between cowpea variety and density in both years (Fig 1). Weed dry matter was much lower in 2003 than in 2002. In both years and for all the varieties weed dry matter were similar at seedling rates of 5 and 7 plants $m^{-2}$.

The observed trend was very apparent in plots seeded to the climbing (Fig. 1b) and erects varieties (Fig. 1d). Weed dry matter Was lowest in plots with cowpea density of 20 plants $m^{-2}$ in all varieties in both years except in the prostrate type in 2002 (Fig. 1). O'Donovan (1994) found a significant reduction in weed dry matter when canola was seed at 200 plants $m^{-2}$. Crop canopy closure may have developed much earlier in plots where the crop was planted at the higher density resulting in shading that reduced weed dry matter. For example, cowpea leaf area index was higher in plots where the crop was planted at 20 plants $m^{-2}$ in both years (Table 3 & 4). Murphy *et al*., (1996) and Chikoye *et al*., (2004) found lower weed dry matter where maize was sown in increased densities through the use of narrow rows.



.***Weed species composition***A biplot of cowpea varieties (main plot) and $N_2$ species diversity is shown in Fig. 2. A total of 26 species were recorded in the entire study area (Fig. 2). *Mimosa invisa* Mart., *Malvastrum coromandelianum* (L.) Garcke and *Digitaria sanguinalis* L. had similar abundance in each of the main plots and are therefore located at the centre of the biplot. This means that the species are ubiquitous and could potentially pose serious management problem in vegetable cowpea production. For example *M. inivisa*, a perennial shrub had mean relative abundance of 31, 36, 43 and 44 % in the erect, climbing, prostrate and semi- bushy varieties, respectively. Although lower in abundance than *M. invisa*, *M. coromandelianum*, a perennial shrub had mean relative abundance of 7, 8, and 7% in he erect, prostate and semi-bushy varieties, respectively. These weeds have been reported as difficult weeds to control in both annual and perennial crops (Alabi *et al*., 2001; Ekeleme *et al*., 2003). $N_2$ diversity was 5.2 and 5.3 in plots seeded to the erect and climbing varieties. This means that there were five very abundant species in each of these varieties. The five very abundant species in the erect variety

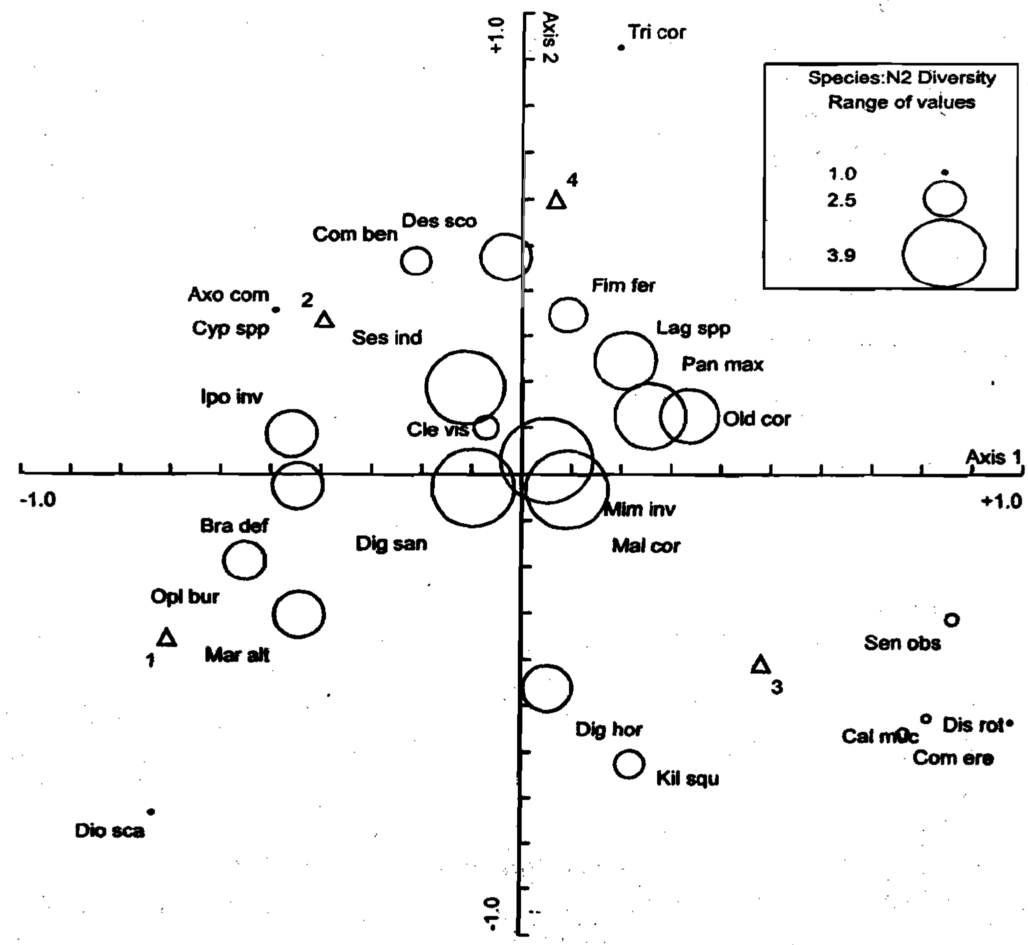


Figure 2: Biplot of N2 diversity of species in four cowpea varieties. Open circles represent species where Asp afr = *Aspilia african* (Pers) C.D Adams, Axo com = *Axonopus compressus* (Sw.) P.Beauv., Bra def = *Brachiaria deflexa* (Schumach.) C.E. Hubbard ex Robyns, Cal muc = *Calopoginium mucunoides* L., Com ben = *Commlina benghalensis* L., Com ere = *Commlina erecta* L.; Cle vis = *Cleome viscose* L., Cyp spp = *Cyperus* species, Des sco = *Desmodium scorpiurus* (Sw.) Desv., Dig hor = *Digitaria horizontalis* L., Dig san = *Digitaria sanguinalis* L., Dio sca = *Diodia scandens* Sw., Dis rot = *Dissotis rotundifolia* (Sm.) Triana, Fim fer = *Fimbristylis ferruginea* (L.) Vahl., Ipo inv = Ipomoea *involucrata* P. Beauv., Kil squ = *Killinga squamulata,* Lag aur = *Laggera aurita* L., *Malvastrum coromandelianum* (L.) Garcke, Mar alt = *Mariscus alternifolius* Vahl., Mim inv = *Mimosa invisa* Mart., Old cor = *Oldenlandia corymbosa* L., Opl Bur = *Oplismenus burmannii* (Retz.) P. Beauv., Pan max = *Panicum maximum* Jacq., Sen obt = *Senna obtusifolia* (L.) Irwin & Barbeby, Ses ind = *Sesamum indicum* L.,Tri cor = *Triumfetta cordifolia* A. Rich. Cowpea varieties with open triangules where 1 = IT86F-1014-1, 2 = Akidienu, 3 = Akidiani, 4 = IT81d-128-14.

includes *M. invisa D. sanguinalis, Brachiaria deflexa* (Schumach.) C.E Hubbard ex Robyns, *Oplismenus burmanni* Retz. and *Mariscus alternifolius* Vahl. These five species accounted for 87% of the abundance in this plot whereas 78% of species abundance in the climbing variety was accounted for by *M. invisa, Ipomoea involucrata* P. Beauv., *Cleome viscose* L., *Sesamum indicum* L., *Commlina benghalensis* L., and *Desmodium scorpiurus* (Sw.) Desv. The prostrate and the semi-bushy varieties had $N_2$ diversity of 4.4 and 4.2, respectively with four species in each of the treatment accounting for > 70% of the abundance. Major species in the prostrate variety were *M. invisa, M. coromandelianum, Digitaria horizontalis* L. and *Killinga squamulata* Thonn. ex Vahl. While *M. invisa, M. coromandelianum, Panicum maximum* Jacq. and *Oldenlandia corymbosa* L. were very dominant in the semi-bushy variety.

The result on weed species diversity in the prostrate and semi-bushy varieties supports the trends in weed density and dry matter observed in these plots. There results suggest that the two varieties were superior to the climbing and erect variety in suppressing weeds and could be suitable short duration cover crops in small-scale farming system in the humid forest fringes.

## REFERENCES

Alabi, B.S., Ayeni, A.O., Agboola, A.A., Majek, B.A. (2001). Giant sensitive plant interference in cassava. *Weed Science* 49:171-176.

Barton, D.L., Thill, D.C., and Bahman, S. (1992). Intergrated wild oat (*Avena fatua*) management affects spring barley (*Hardeum vulgare*) yield and economics. *Weed Technology* 6: 129-135.

Blumenthal, M.J., and Ison, R.L. (1994). Plant population dynamics in subterranean clover and murex medic swards. II: Plant population density. *Australian Journal of Agricultural Resources* 45: 929-944.

Carlson, H.L., and Hill, J.E. (1985). Wild oat (*Avena fatua*) competition in spring wheat: Plant density effects. *Weed Science* 33: 176-181.

Chikoye, D., Schulz, S. and Ekeleme, F. (2004). Evaluation of integrated weed management practices for maize in the northern Guinea savanna of Nigeria. *Crop Protection* (in press).

Cudney, D.W., Jordan, L.S., Holt, J.S., and Reints, J.S. (1989). Competitive interactions of wheat (*Triticum aestivum*) and wild oats (*Avena fatua*) grown at different densities. *Weed Science* 37: 538-543.

Ekeleme, F., Akobundu, I.O., Fadayomi, R.O., Chikoye, D. Abayomi, Y.A. (2003). Charaterization of legume cover crops for weed suppression in the moist savanna of Nigeria. *Weed Technology* 17: 1-13.

Fukai, S., and Silsbury, J.H. (1978). A growth model for *Trifolium subterraneum* L. swards. *Australian Journal of Agricultural Resources* 29: 51-65.

Haizel, K.A. (1972). The effect of plant density on the growth, development and grain yield of two varieties of cowpea, *Vigna unguiculata* (L.) Walps. *Ghana Journal of Agricultural Science* 5: 163-171.

Hill, M.O. (1973). Diversity and evenness: A unifying notation and its consequences. *Ecology* 54: 427-432.

Hume, L. (1985). Crop loses in wheat (*Triticum aestivum*) as determined using weeded and nonweeded quadrats. *Weed Science* 33: 734-740.

Jagtap, S.S., Alabi, R.T., and Adeleye, O. (1998). The influence of maize density on resource use and productivity: an experimental and simulation study. *African Crop Science Journal* 6: 259-272.

Little, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D. (1996). *SAS Systems for Mixed Models. Statistical Analysis Systems* Inc. Cary, NC, USA. 633pp.

Ludwig, J.A., and Reynolds, J.F. (1988). *Statistical Ecology: A primer on methods and computing.* A wiley Interscience Publication. 337pp.

Murphy, S.D., Yakabu, Y., Weise, S.F., Swanton, C.J. (1996). Effect of planting pattern and interrow cultivation on competition between corn (*Zea mays*) and late emerging weeds. *Weed Science* 44: 856-870.

O' Donovan, J.T. (1994). Canola (*Brassica rapa*) plant density influence Tartary Buckwheat (*Fagoprum tataricum*) interference, biomass, and seed yield. *Weed Science* 42: 385-389.

Orwick, P.L., and Schreiber, M.M. (1979). Interference of redroot pigweed (*Amarathus retroflexus*) and robust foxtail (*Setaria viridis* var *robusta-alba* or var *robusta-purpurea*) in soybeans (*Glycine max*). *Weed Science* 27:665-674.

Osei-Yeboah, S., Linday, S.J.I., and Gumbs, F.H. (1983). Estimating leaf area of cowpea (*Vigna unguiculata* [L.] Walp) from linear measurement of terminal leaflet. *Tropical Agriculture* 60: 149-150.

Smilauer, P. (1992). *CanoDraw, Ithaca, Microcomputer Power*, New York, USA.

Ter Braak C.J.F. 1990. CANOCO *a FORTRAN program for canonical community ordination by (partial) (detrended) canonical) correspondence analysis, principal components analysis, and redundancy analysis version 3.10*, Microcomputer Power, Ithaca, New York, USA.