Studies on the effect of density and duration of *Cyperus rotundus* interference on vegetable cowpea production in an Ultisol.

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Abstract: Two experimental studies were conducted at Michael Okpara University of Agriculture, Umudike research farm (1) to examine the effect of densities of *Cyperus rotundus* (purple nut sedge) on vegetable cowpea (IT 81D-125-14 – a semi-bushy cultivar) and (2) to examine the effect of the duration of *C. rotundus* competition on vegetable cowpea growth, yield and dry matter production in soils characterized as Ultisol. The experiments were laid out in a completely randomized design (CRD). The first experiment had six repetitions and seven treatments consisting of seven different *C. rotundus* densities (0, 25, 50, 100, 150, 200 and 250 plants/m^2). The second experiment had 10 treatments repeated four times. The cowpea seeded at density of 200,000 plants/ha and *C. rotundus* was planted at 150 plants/m^2. Results obtained showed that increasing density of *C. rotundus* caused inter-specific competition between cowpea and *C. rotundus*, which led to a significant reduction in cowpea vegetative growth and dry matter production. Nodulation in cowpea were depressed with increasing density of *C. rotundus*, as a result of the competition. In experiment two, there was a significant increase in the height of both plants overtime ($P<0.05$). Leaf area development, yield and dry weight in cowpea followed a similar trend as the growth in height. There was significant increase in the density of *C. rotundus* as duration period increases. At 4 WAE, cowpea yield was reduced to 46% due to competition with *C. rotundus*. Thus, *C. rotundus* was more competitive and reduced cowpea yields when the duration of competition exceeded 3WAE.

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1. Introduction

Cowpea (Vigna unguiculata (L) Walp) is a crop of tremendous economic value being a major source of protein in West and Central Africa where more than 60% of the world's cowpea is being produced. Rural families derive food and animal fodder from this crop (Tarawali *et al*., 1997; Asiwe, 2007). It is of a major importance to the livelihood of millions of relatively poor people in less developed countries of the tropics (Fery, 1985, 1990). It is a fruit vegetable produced and consumed throughout Nigeria. The immature pods and seeds are used for many purposes, especially for salad making. It can also be processed and canned. The fruits are used fresh or in dry form. In West Africa and many parts of the world cowpea [*Vigna unguiculata* (L) Walp] is an important grain legume (Takim and Uddin, 2010). Total worldwide production of cowpea is estimated at 3.3 million tons (FAO, 2001) of dry grain of which 64% is produced in Africa. Conservative estimates suggest that 12.5 million ha are planted annually to cowpea around the world. Of this area, about 9.8 million ha are planted in West Africa, making it the region with the largest production and consumption of cowpea in the world (CGIAR, 2001). Cowpea production is regarded as an integral part of traditional cropping system throughout Africa (Isubikalu *et al*., 2000).

The detrimental effects of weeds in Africa far exceed the world average. It is estimated that in Africa yield losses range from 25% to total crop failure, depending on many factors among which weed pressure, availability of improved weed control technology, cost of weed control and level of weed management practiced by farmers (Akobundu, 1987; Van Rijn, 2000). Farmers obtained low average yield due to these field pests. For instance, average world yield of cowpea grain is quite low at less than 0.3 ton/ha. (Takim and Uddin, 2010). These major pests of cowpea in the humid tropics are weeds (Ayeni, 1992). Tijani-Eniola (2001) reported that weed could cause yield losses ranging from 50 to 80 %. Crop losses by weeds could be aggravated by delay in weeding or inability to weed throughout the entire crop growth period. However, studies of threshold levels of weeds have shown that complete weed elimination is not essential for high yields (Sangakkara, 1999). Direct losses caused by weeds vary from crop to crop and from one agro-ecological zone to the other for the same crop. The importance of weeds is widely acknowledged and mankind is still far from dealing with them effectively (Rehm and Espig, 1991). Worldwide, 13% loss of agricultural production is attributed to weeds, in spite of the control measures taken by farmers. If no action were taken to protect crops from weeds, the losses would amount to 30% (Oerke *et al.*, 1994).

Vegetable cowpea has been reported to perform better than cowpea grown for grains, under the humid conditions of the forest belt of southern Nigeria (Uguru, 1996). In southeastern Nigeria, *Cyperus spp.* are a major constraint to vegetable cowpea production due to their mode of propagation underground stolons and tubers. Based on distribution (92 countries) and agricultural impacts (interference with over 50 crops) purple nutsedge (*Cyperus rotundus*) is the world's worst weed (Bangarwa *et al*. 2008). It has been reported that in the United States for example, purple nutsedge is the worst weed of cucurbit and fruiting vegetable crops in the southern states (Webster *et al*. 2008). Purple nutsedge is a serious weed in rice, sugarcane, cotton, maize and vegetable crops (Bendixen and Nandihalli 1987). It is an important weed in peanut, sorghum and soybean crops (Bendixen and Nandihalli 1987); and in Florida and other tropical and subtropical regions, it is the most troublesome weed in peppers (*Capsicum* spp.) grown in soils without methyl bromide fumigation (Morales-Payan *et al*., 2004). Purple nutsedge infestation causes significant reduction in production of vegetable and grain crops, including tomato (44% to 53% reduction), garlic (89%), okra (62%), cabbage (35%), lettuce (54%), beans (81%), bell pepper (32% to 73%), carrot (39 to 50%), cucumber (43%), radish (70%) and rice (38% to 43%) (Okafor and De Datta, 1976, Yandoc *et al*. 2006). Increased densities of nutsedge are correlated with decreased crop yield. The ability of purple nutsedge to reproduce prolifically by asexual means, its complex network of underground structures (tubers, basal bulbs, roots and rhizomes) and its adaptation to high temperatures, solar radiation and humidity, have turned it into a serious agricultural weed in tropical, subtropical and arid regions (Bendixen and Nandihalli, 1987; Wills 1987, in Santos *et al*., 1998; Warren and Coble, 1999; Travlos *et al*., 2009). There is limited literature on the competitive effects of *Cyperus spp.* in southeastern part of Nigeria. This study was therefore designed to investigate the effect of *Cyperus spp.* interference (density and duration) on the production of vegetable cowpea.

2. Materials and Methods

Pot experiments were conducted at the research farm of Michael Okpara University of Agriculture, Umudike to measure the effect of density and duration of *Cyperus rotundus* on *Vigna unguiculata* growth and yield in soils of the forest zone of Southeastern Nigeria. Materials used in this experiment were fresh viable tubers of *Cyperus rotundus* dug out from the University research farm and viable seeds of cowpea (IT81D-128-14 – semi bushy cultivars). The soil for the study was collected from the experimental farm at a depth of about 0 – 15 cm. The soil sample was bulked, heat sterilized and mixed with poultry droppings and river sand (for aeration and improving the soil texture) in the ration 3:2:1 of top soil (sterilized), poultry droppings and river sand respectively.

For weed density effect (Experiment one), the experiment was laid out in completely randomized design (CRD) with six replicates and eight treatment consisting of seven different *C. rotundus* densities (0, 25, 50, 100, 150, 200 and 250) while the duration effect (Experiment two), was also laid out in Completely Randomized Design (CRD) with four replications. The treatments comprised fixed density of 150 weed plant per m^2 which were weeded at 1, 2, 3, 4, 5, 6, 7, 8, 9 weeks after emergence and kept weed free to harvest while the tenth pot has no weed (control). The number of weeds after emergence before *Cyperus rotundus* was weeded represents the duration of competition. Cowpea density was based on field density of 20,000 plants per hectare or one plant per 0.0531 m^2. Cowpea (IT81D-128-14 – a semi-bushy cultivar) were sown at the rate of three (3) seeds per pot and the seedling were thinned down later to one plant per pot a week after sowing.

Soil moisture and nutrient were adequately supplied throughout the duration of the experiment to avoid stress due to moisture and or nutrient. Hand weeding was done regularly at the initial weed removal to keep the plot weed free. Insect pest was controlled using Dichlorvos (DDV) at 5 ml in 1 litre of water from cowpea flowering to harvest.

Experiment one examined densities and data were collected weekly on cowpea and *C. rotundus* plant height, leaf area, leaf number and density of plant population in each pot. At the first two weeks, two individual/stand of *C. rotundus* weed were selected and leaf area was taken on the longest leaf in both, this was applicable to cowpea also. The rest of the data was collect on one single or individual weed stand that was tagged. Data was also collected on the time of flower initiation in both cowpea and *C. rotundus*. At 30 DAP, half of the experiment were harvested and data taken on the fresh and dry weight of both the shoot and root including the tubers found.

At flowering (40 DAP), the rest were harvested and the experiment was terminated.

Experiment two examined time of weeding and data were collected on the following parameters for both cowpea and *C. rotundus*; plant heights, leaf area and leaf area index, and number of branches (cowpea alone) at maturity. Leaf area was estimated by measuring the leaf length and the leaf width from the tip of the broadest (centre of the leaflet)/ leaf (for *C. rotundus*). For cowpea, leaf-length was measured from the central leaflet as the two lateral leaflets were symmetrical. The product of the leaf length and the width for the cowpea and *C. rotundus* were multiplied by 2.325 and 1.012 as recommended by Osei-Yeboah (1983). For *C. rotundus*, shoot fresh weight, shoot dry weight, were taken weekly. Tuber fresh weight and dry weight and tuber number were taken at the end of the experiment. For cowpea, number of pod, pod fresh weight, shoot fresh and dry weight, root dry weight and number of nodules were recorded at harvest. All the data were subjected to analysis of variance (ANOVA) using the generalized linear model procedure in SAS (PROC GLM) (SAS, 1998).

3. Results and Discussion

3.1 Experiment one

The effect of different shoot derivation of *Cyperus rotundus* on the leaf are cowpea and *C. rotundus* at 14 days after planting (DAP) is presented in Figure 1. This shows that as shoot density of *C. rotundus* increased, the leaf are of the cowpea decreased. Reduction in leaf area was more pronounced at shoot density of 100 plants m^{-2}. No definite reason could be given for the sharp decline in the leaf area of cowpea at a *C. rotundus* shoot densities of 100 plants m^{-2} compared with higher shoot densities. Compared with cowpea grown without *C. rotundus*, the highest population of *Cyperus* caused over 35% reduction in leaf area of cowpea. This result agreed with Johnson and Mullinix (1999), who reported that *C. rotundus* caused 47% reduction in the yield of *Cucumis sativa* at a density of 950 plants m^{-2}. It is also clear from Figure 1 that as the mean leaf area of *C. rotundus* increased that of cowpea decreased with corresponding increasing in shoot density of *C. rotundus*. Cowpea leaf area at *C. rotundus* shoot density of 50 plants m^{-2} was however similar to the leaf area of cowpea in the weed free pot. In the case of *C. rotundus*, the mean leaf area increased as the shoot density increased from 25 to 250 plant m^{-2}.

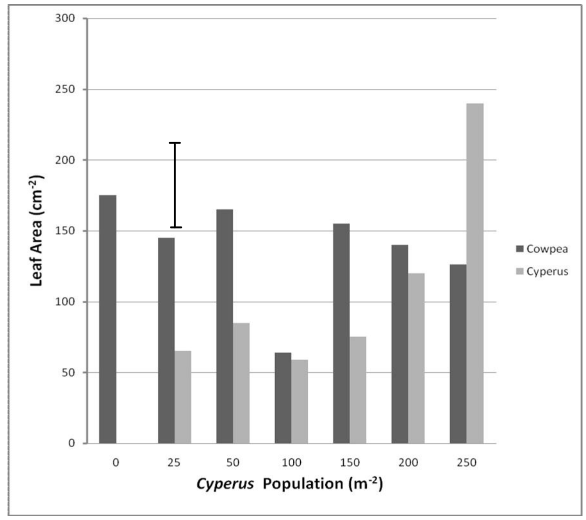


Figure 1: The effects of different densities of *C. rotundus* on the leaf area of *C. rotundus* and cowpea at 14 days after planting (DAP)

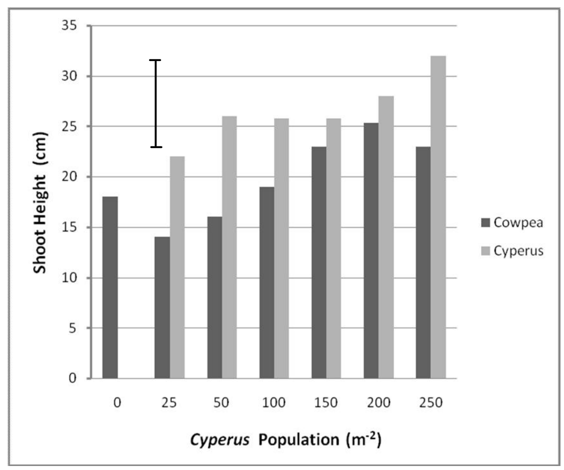


Figure 2: The effects of different densities of *C. rotundus* on plant height (cowpea and *C. rotundus*) at 21 days after planting (DAP).

The effect of *C. rotundus* shoot density shoot density on the height of cowpea at 21 day after planting (DAP) is shown in Figure 2. Cowpea height in the treatment without *C. rotundus* shoot density represents the potential cowpea height increased as the shoot density of *C. rotundus* shoot density of 200 plants m^{-2}. The height of cowpea in the cowpea/*Cyperus* treatment was also higher than that in the cowpea treatment without *Cyperus* except in the treatment where *Cyperus* was planted at 25 and 50 plants m^{-2}. This trend suggests that intra specific competition for light between cowpea and *C. rotundus*. It was also shown from the same graph that *C. rotundus* height increased with increase in the shoot density, having the lowest and highest at 25 and 250 plants m^{-2} densities. These suggest that intra specific competition for light between *C. rotundus* plant may have occurred. These results support the findings of Johnson and Mullinix (1999) on intraspecific competition in *C. rotundus*.

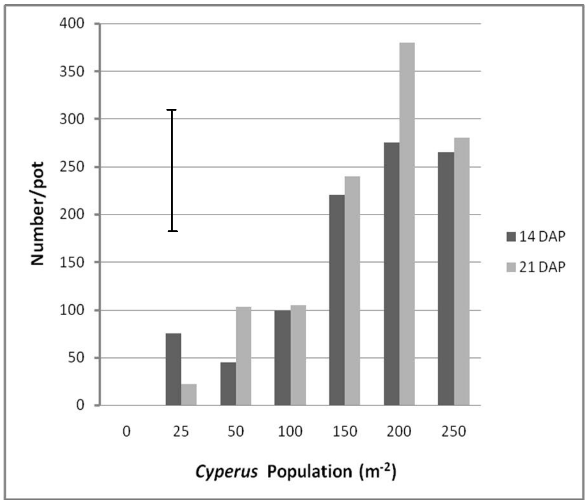


Figure 3: Changes in *Cyperus rotundus* shoot density over time

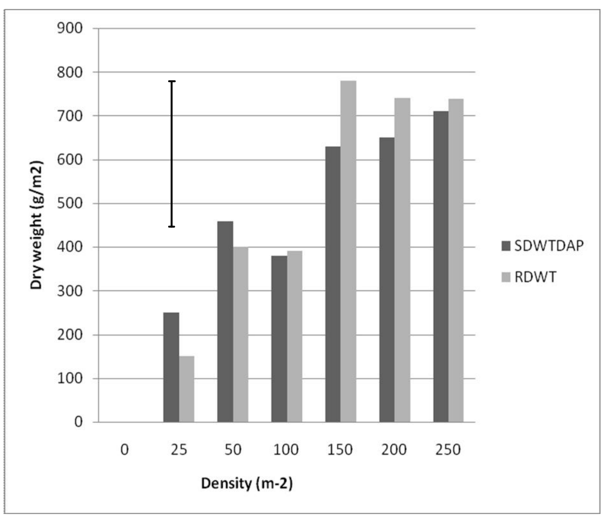


Figure 4a: The effect of different densities of *C. rotundus* on the leaf area of cowpea shoot and root dry weight at (SDWT and RDWT) at 14 DAP.

Figure 3 show *C. rotundus* shoot dynamics at different densities at 14 and 21 DAP. The graph showed that the density of *C. rotundus* increased over time. Such an increase depicts the potential of *C. rotundus* to propagate in large number with time. For example, Gifford and Bayer (1995) reported that a healthy plant of *C. rotundus* might produce over 400 – 500 tubers a year. This result could mean the production up to 400 shoot per tuber if the tuber is viable.

The relationship between different shoot densities of *C. rotundus* on the shoot and root dry weight at 40 days after planting is shown in Figure 4a. The result followed the same pattern observed with leaf area, i.e. as *C. rotundus* shoot density increased, the root and shoot dry weight increased also with a deviation at the density of 100 plants m^{-2}. Also, between the densities of 150 and 250 plants m^{-2} there was no significant increase in both root and shoot dry weights.

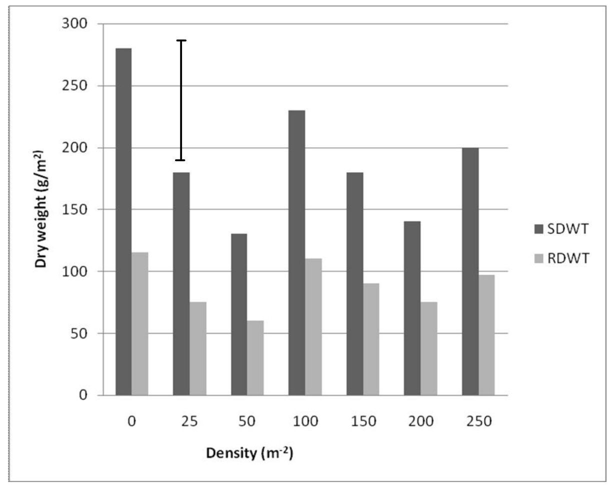
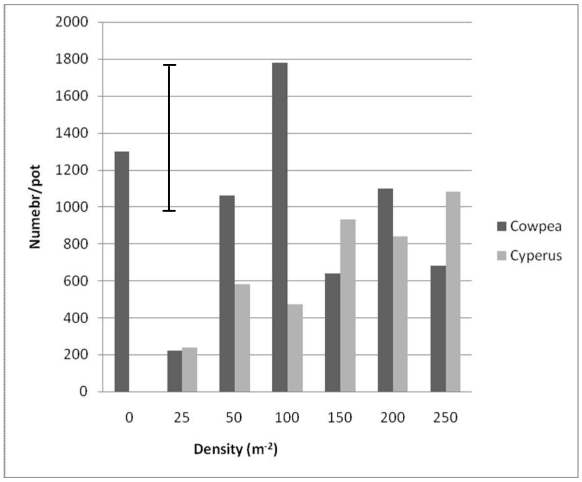


Figure 4b: The effect of different densities of *C. rotundus* on the Shoot and root dry weight (SDWT and RDWT) of cowpea at 40 DAP.

Figure 4b shows the effects of different shoot densities of *C. rotundus* on cowpea shoot and root dry weights at 40 DAP. There was a general tendency ‘hough oscillating for cowpea shoot and root density. This trend was observed at shoot density of between zero to 50 plants m^{-2} and 100 to 200 plants m^{-2}. However, the lowest shoot and root dry weights were observed at 50 shoot density m^{-2} of *C. rotundus*. Compared with the weed free treatment, this would translate to over 59% and 40% reduction in cowpea shoot and root dry weight respectively. The data suggest that cowpea produce more dry weight at monoculture than when competing against *C. rotundus* and this is consistent with the finding by Santos *et al.*, (1997).

The effects of different *C. rotundus* shoot density on *C. rotundus* tuber formation and cowpea nodulation at 40 days after planting (DAP) is shown in figure 5. The graph shows the effect of different shoot density on *C. rotundus* tuber formation. Tuber



The effects of different *C. rotundus* shoot density on *C. rotundus* tuber formation and cowpea nodulation at 40 days after planting (DAP).

formation in *C. rotundus* increased as shoot density increased except at 100 and 200 plants m^{-2}.

However, nodulation in cowpea generally increased with some oscillation as *C. rotundus* short density increases. For example, at 100 and 200 plants m^{-2} where there was a decline in *C. rotundus* tuber formation, cowpea nodulation increased rapidly showing that tuber formation affects nodulation significantly. As shown from the graph, nodulation in cowpea peaked at 100 plants m^{-2} shoot density than at monoculture (Cowpea weed free pot) and the least at 25 plant m^{-2} shoot density. At 50 and 250 plants m^{-2} there was a reduction, which can be translated to over 19% and 47% reduction in cowpea nodulation respectively when compared with the weed free treatment (at monoculture). This suggests strongly that increasing *C. rotundus* shoot density affects cowpea nodulation negatively.

Figure 6 shows the effects of different shoot density of *C. rotundus* on total *Cyperus* biomass and total cowpea biomass at 40 DAP. There was a general tendency though oscillating for both total *Cyperus* biomass and total cowpea biomass to increase in *C. rotundus* shoot density. However, the lowest mean in total *Cyperus* biomass was observed at 25 plant m^{-2} and total cowpea biomass at 50 plants m^{-2} *C. rotundus* shoot density. At 50 plants m^{-2} shoot density; cowpea recorded the least total cowpea biomass, which can be translated to over 54% reduction when compared with the weed free treatment. This finding suggests that there was a strong inter specific competition between the weed and the crop. Quayyum *et al*. (2000) also reported that Purple nutsedge suppresses the growth of adjacent plants on other related crops.

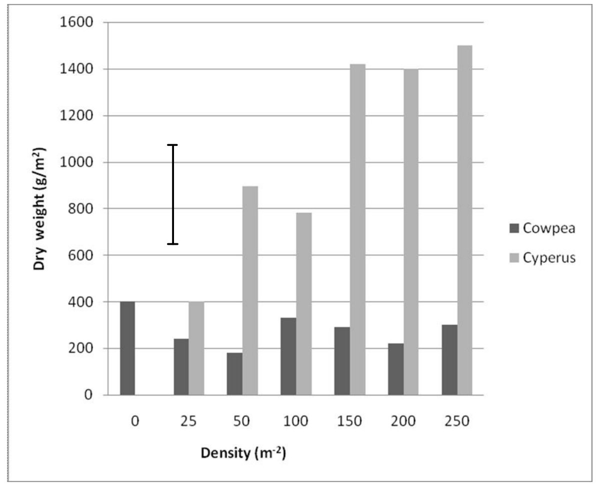


Figure 6: The effect of different densities of *C. rotundus* on total *C. rotundus* and cowpea dry weight at 40 DAP.

3.2 Experiment two

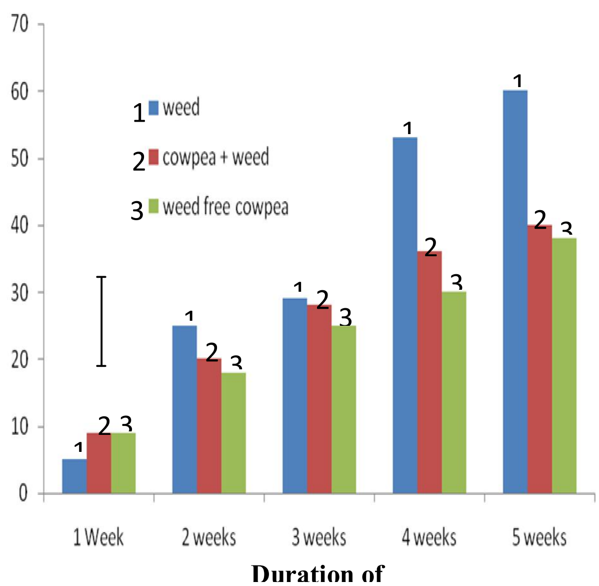


Figure 7: Effect of *C. rotundus* on *V. unguiculata* height within 5 weeks

The effect of duration of *C. rotundus* competition on Cowpea height is shown in figure 7. There was significant increase in the height of both the crop and the weed over time. At one week crop emergence (WAE), cowpea was 3.4 cm taller than the weed. But by the fifth week after emergence, *C. rotundus* height more or less doubled the height of cowpea. The trend suggests that *C. rotundus* was more competitive than the cowpea. A similar trend was observed by Olansantan and Lucas (1992), who noted that crop height is an important feature that determines competitiveness of plants for light.

The effect of duration of *C. rotundus* competition on cowpea leaf area is shown in figure 8. Leaf area development in cowpea followed similar trend as the growth in height (figure 8). Cowpea developed smaller leaves under competition with *C. rotundus*. This trend was more pronounced after the third week suggesting that 3 weeks was very critical to cowpea growth particularly in the development of the leaf area.

C. rotundus shoot fresh weight and dry weight increased over time with senescence of lower leaves becoming evident after 6 weeks. There was significant difference in cowpea shoot dry weight over time also. As the duration of cowpea competition with *C. rotundus* increases, the cowpea shoot dry weight decreases. For example, comparing *C. rotundus* competition with cowpea for week 1 and week 9, 86% reduction in crop biomass occurred. Comparing competition for week 5 with weed free, 16% reduction in cowpea biomass occurred. It is therefore important for people to weed within the third and fourth week after crop emergence. This supports Aldrich (1984) that as weed weight increases duration of competition increases, crop yield decreases. Also Gill (1982), reports that magnitude of competition depends upon the weed density (weight), weed type, crop variety, stage of growth of both crop and weed, and duration of competition.

Cowpea number of pods per plant and pod fresh weight followed a similar trend as the growth in height (Table 1). Cowpea produced lower number of pods per plant and pod fresh weight under competition with *C. rotundus*. This trend was not pronounced after the fifth week suggesting that 3 – 5 week are very critical to cowpea number of pod per plant and pod fresh weight. This also indicates that as the time allowed for cowpea to compete increase, the cowpea yield decreases. Comparing the weed free cowpea yield with the 4th and 6th week, 43% and 73% yield reduction respectively was observed. This showed that after 5 weeks of weed competition with *C. rotundus*, cowpea yield was significantly suppressed (Ayeni and Akobundu, 1984; Akobundu, 1982).

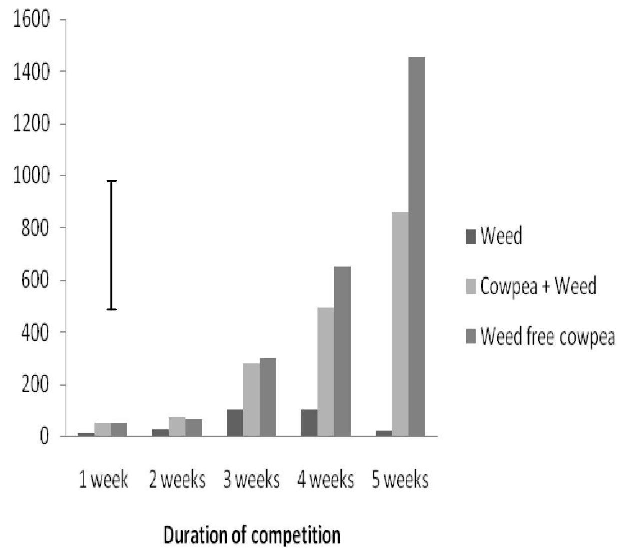


Figure 8: Effect of *C. rotundus* on *V. unguiculata* leaf area within 5 weeks

There was a significant increase in the weed tuber number/m^2 and tuber dry weight/m^2 decreased as the duration of competition increases and the decrease was more pronounced after 5 weeks of competition (Table 2). Cowpea nodule number decreased after 3 weeks, again suggest that nodulation was depressed by *C. rotundus*. Like most C_4 plants, purple nutsedge is shade intolerant, and can be suppressed by a closed crop canopy, although tubers remain viable and send up new shoots when the canopy is removed (Holm *et al*., 1991).This is an indication that 3 weeks after planting is critical for cowpea growth. This result agrees with Ahlawat, *et*

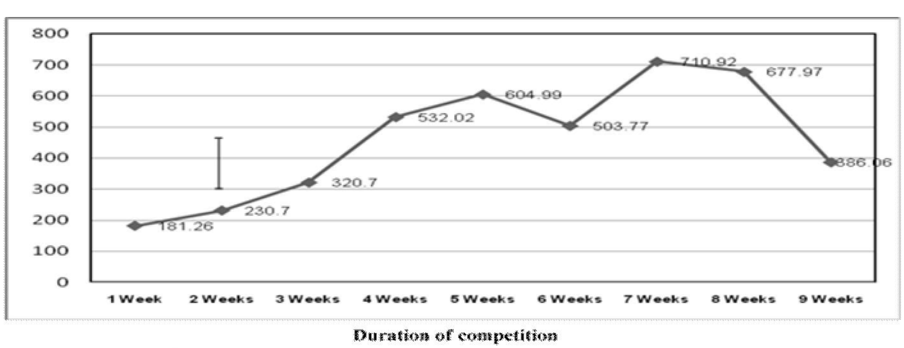


Figure 9: Change in *Cyperus rotundus* density over time.

Table 1: Relationship between weed density, cowpea shoot dry weight, number of pods and pod fresh weight at various periods of competition.

Duration of competition	Weed Shoot fresh weight	Weed Shoot dry weight	Crop Shoot dry weight	No. of pods per plant	Pod fresh weight (t/ha)
	g/m^2				
1 Week	10.70^e	0.70^d	17.70^a	61^a	25.38^a
2 Weeks	57.23^e	7.45^d	7.18^{ab}	47^{ab}	9.27^{bc}
3 Weeks	198.14^{de}	24.22^d	10.36^{ab}	44^{ab}	19.44^{ab}
4 Weeks	475.52^d	83.22^d	10.23^{ab}	38^{ab}	11.05^{bc}
5 Weeks	468.15^d	83.22^d	10.23^{ab}	42^{ab}	17.20^{ab}
6 Weeks	2636.14^b	893.41^b	5.56^b	18^b	5.60^c
7 Weeks	2908.71^b	825.20^{ab}	4.61^b	17^b	6.40^c
8 Weeks	3379.03^a	667.32^b	4.27^b	18^b	7.36^c
9 Weeks	1766.52^c	373.53^c	10.39^{ab}	13^b	3.82^c
Weed free	-	-	10.39^{ab}	67^b	29.26^a

Within each column, means with different letter(s) are significantly different ($P<0.05$) according to Duncan's New Multiple Range test.

Table 2: Effect of *Cyperus esculentus* on *Vigna unguiculata* root dry weight and nodulation

Duration of competition	Weed	(*C. esculentus*)	Cowpea	
	Tuber No./m^2	Tuber dry wt./m^2	Nodule No./m^2	Root dry weight/m^2
1 Week	24^d	2.73^d	2^c	16.22^{ab}
2 Weeks	57^d	10.89^d	17b^c	9.81^{cd}
3 Weeks	99^d	11.11^d	32^{ab}	12.10^{abc}
4 Weeks	268^d	31.36^d	25^{abc}	11.72^{bc}
5 Weeks	918^c	140.02^e	13^{bc}	12.15^{abc}
6 Weeks	1243^b	216.81^c	20b^c	6.21^{cde}
7 Weeks	1400^b	333.15^b	19^{bc}	6.21^{cde}
8 Weeks	1784^a	512.76^a	16^{bc}	4.76^{de}
9 Weeks	965^c	341.38^b	3^c	2.82^e
Weed free	-	-	51^a	19.02^a

Within each column, means with different letter(s) are significantly different ($P<0.05$) according to Duncan's New Multiple Range test.

al. (1981) that the first 4 – 8 weeks are the most critical period for weed competition in cowpea, peas and mung bean.

There was a significant increase in the density of *C. rotundus* over time (Figure 9). This increase in density was from 150 plant/m2 at the unset of the experiment. After 7 weeks the density of weeds started senescing. This may be as a result of intra spacing between the *C. rotundus* but the reduction is more than twice the number planted. On the graph above, where there is sharp increase in the weed density (3 weeks) and (7 weeks) indicates that they are the critical period for cowpea in *C. rotundus* infested field.

4. Conclusion

4.1 Experiment one

The results obtained from the study showed that increasing density of *C. rotundus* has significant negative effect on cowpea vegetative growth and dry matter production.

Since *C. rotundus* tuber has a very high multiplication ability, and very short reproductive life cycle, effective control within 14 day of the weed emergence to prevent tuber formation and multiplication is necessary. This may be achieved through an integrated system of cultural and mechanical weed control practice (John and Mullinix, 1998).

Based on the result from shoot density of 50 plants m-2, cowpea farmers should not allow *C. rotundus* density to exceed 50 plants m-2 before they effect control. Because above this density cowpea experience significant reduction in vegetative growth, dry matter production, nodulation and with a potential reduction in pod yield.

4.2 Experiment two

This study was able to show that *Vigna unguiculata* (cowpea) was less competitive than *C. rotundus* (yellow nut sedge). After three weeks of interference, cowpea growth and yield were depressed. Therefore 3 weeks after emergence appears to be critical for cowpea in *Cyperus rotundus* infested field. Based on this observation, cultural control strategies in these crops should start before the third week to enhance yield and reduce the adverse impact of these weedy species in vegetable cowpea field.

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