Scientific Research Publishing

American Journal of Plant Sciences, 2020, 11, 276-284
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Evaluation of Weed Incidence and Biomass in Coffee Intercropped with Oil Palm in Avenue and Hollow Square Arrangement in Nigeria

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How to cite this paper: Famaye, A.O., Adeosun, S.A., Ayegboyin, K.O., Adejobi, K.B., Akanbi, O.S.O. and Okunade, A.F. (2020) Evaluation of Weed Incidence and Biomass in Coffee Intercropped with Oil Palm in Avenue and Hollow Square Arrangement in Nigeria. *American Journal of Plant Sciences*, **11**, 276-284.
https://doi.org/10.4236/ajps.2020.112021

Received: November 28, 2019
Accepted: February 25, 2020
Published: February 28, 2020

Abstract

Weed incidence and biomass in tree crop plantations are mainly influenced by environmental, farm management practices and cropping systems. Manipulation of intercropping systems to improve weed management in coffee intercropped with oil palm requires a better understanding of spatial and temporal dynamics of weeds. To evaluate the effect of weed incidence and biomass in coffee intercropped with oil palm in avenue and hollow square arrangement, a study was carried out in Cocoa Research Institute of Nigeria (CRIN) in two locations. The locations are Idi-Ayunre (7˚25'N, 3˚24'E) (an alfisol) and Uhonmora (6˚5'N, 5˚50'E) (ultisol) in rainforest and derived savannah parts of Nigeria respectively. The experiment had three treatments comprising coffee sole (control), coffee with oil palm (Hollow square) arrangement and coffee with oil palm (Avenue) planting. Coffee was planted 3.0 m apart while oil palm was planted 9 m apart. Equal size of land area was used for coffee in each treatment. The experimental design was Randomized Complete Block (RCBD) with three replicates. Data on vegetative growth of coffee, weed incidence and biomass were taken at three-monthly intervals. The result showed that coffee/oil palm (Hollow Square) had the least weed incidence and biomass closely followed by coffee/oil palm (Avenue) planting. The control had the highest weed biomass which was significantly different from Hollow square and Avenue planting at $P \leq 0.05$. The morphological parameters on coffee followed the same pattern but Hollow square arrangement was significantly higher than Avenue and control at $P \leq 0.05$.

Keywords

Evaluation, Weed, Incidence, Biomass, Coffee, Intercropped, Oil Palm, Hollow Square, Avenue Arrangement

1. Introduction

Weed flora has changed over the past century, with either increasing or decreasing species abundance depending on the management [1] [2] [3]. In an integrated approach, the development of cropping systems such as appropriate spatial arrangements and the efficient intercropping systems will help crops themselves to compete with weeds [4]. Manipulation of cropping systems for the purpose of improving integrated weed management requires a good understanding of weed dynamics and influences of crop and soil-related factors on weed life cycles [5].

Weeds have been implicated as the most damaging of crop pests because weed communities continue to adapt in response to new management measures [6]. Weed presence may cause more problems in some cropping systems, especially in organic farming where application of systemic agrochemicals is not allowed. Belde *et al*. [7] found that the composition of weed seed in the soil seed bank hardly changed six years after converting a farm from conventional to organic systems. However, many other investigators showed positive effect of cropping systems on biodiversity of farm lands [8] [9] [10]. Weed seed banks may reflect the status of weed population in the present and the past and could be regarded as an indicator of the impact of crop management [11]. Furthermore, weed causes reduction in crop yield and extra cost in the total labour use in crop production. Akobundu [12] stated that weed causes 65% reduction in yield of root and tuber crops and takes 25% of total labour use in production. Weed control constitutes the greatest problem during the early year of field establishment of coffee plant when they have not formed sizeable canopy [13]. Weed still appears to be the most deleterious constraint causing berry yield reduction. It is one of the commonest agronomic problems in coffee after planting on the field [14].

Hoe weeding which is the traditional method of weed control in Nigeria is very expensive, labour intensive, time consuming and exposes coffee soil to erosion [15]. Herbicides are very expensive for peasant farmers who are the major coffee growers in Nigeria. The current high cost of labour and unavailability of herbicide have necessitated the need for the cropping system manipulation to reduce weed incidence in coffee and equally improve its vigour and survival rate at early year of field establishment before the canopy closes.

Weed control through farming system practice of planting food crops has been found to suppress weed [16] [17] [18]. Intercropping had been reported to increase crop diversity, biological stability of the ecosystem and labour efficiency [19]. Intercropping in coffee to provide food and income for the farmers is usually possible at the juvenile stage before the leaf canopy closes [20]. With the global food crisis, intercropping coffee with tree crops of economic value that can still be together for years beyond the juvenile stage is of vital importance. Therefore, the objective of this study was to evaluate the incidence and biomass of weed in coffee intercropped with oil palm in Avenue planting and Hollow square arrangement.

2. Materials and Methods

The study was carried out in Cocoa Research Institute of Nigeria (CRIN) in two locations between year 2012 and 2013 covering two rainy seasons and two dry seasons. The rainy season which runs from April to October is characterized by heavy rains, low ambient temperature and high humidity; while dry season running from November to March is characterized by little or no rain, high ambient temperature and very low humidity. The locations are Idi-Ayunre (7˚25'N, 3˚24'E) (an alfisol) and Uhonmora (6˚5'N, 5˚50'E) (an ultisol) in rainforest and derived savanna zones of Nigeria respectively.

The coffee (*Coffee canephora*) seeds were obtained from CRIN research plot and raised into seedlings in CRIN central nursery. Oil palm seedlings (Tenera variety) were obtained from National Institute for Oil Palm Research (NIFOR), Benin City, Edo State, Nigeria. Plantain suckers were obtained from CRIN as shade for coffee seedlings at establishment.

The experiment had three treatments comprising of coffee sole (control), coffee/oil palm (Avenue) planting and coffee/oil palm (Hollow square) arrangement. The experiment was laid out in randomized complete block design with three replications. In Avenue planting, one line in three of palms omitted and the space planted with coffee. Hollow square treatment was created by omitting one palm out of each square of nine palms planted with coffee; while control was pure stands of coffee and pure stand of oil palm (Figure 1). Coffee was planted 3 m × 3 m plant spacing, while oil palm was planted 9 m × 9 m. The plantain was planted at 3 m × 3 m as shade crop at different geometry of coffee.

Weeding was carried regularly at 3 months interval during the experiment. Quadrants of 30 cm × 30 cm were used to take weed samples per treatment before each time of weeding.

Data collected on physical and chemical properties of the soil at the beginning of the experiment through soil sampling and laboratory assay. Weed species were identified and collected by throwing a 30 × 30 cm quadrant three times per plot. Fresh and dry weight of the weed after oven drying for 72 hours to a constant weight at 85˚C was determined. The results obtained were subjected to statistical analysis and LSD was used to separate the means that were significant.

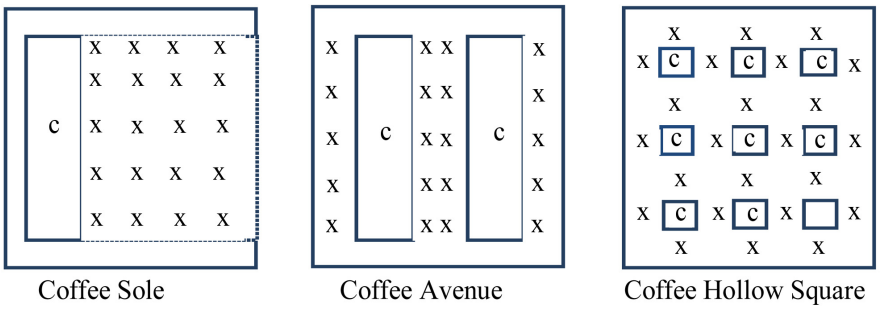

Figure 1. Lay-out of the different arrangements of intercrop of oil palm with coffee. Key: C: Coffee stands; X: Oil palm stands.

3. Results and Discussion

The result of the initial physical and chemical properties of the soils used for the experiments is presented in Table 1. The particle-size analysis of the soils of both Idi-Ayunre and Uhonmora experimental sites showed that the soils were sandy loam, Alfisols and Utisols respectively [21]. The silt and clay contents of the soils at both locations (18.40% and 21.20%) were below the 32% estimated to be adequate for soils considered to be ideal for tree crops production especially coffee [22]. Based on the established critical levels for soils in South-Western Nigeria, the soils at Idi-Ayunre and Uhonmora were acidic with pH ranging between 6.2 - 5.2. The total nitrogen of both Idi-Ayunre and Uhonmora soils (0.07% and 0.09%) was less than 0.15% which is considered optimal for most crops including coffee. The soils also had low CEC [23]. The available P (7.40 and 7.15 mg/kg for Idi-ayunre and Uhonmora respectively) is considered inadequate for coffee and oil-Palm [22]. Only Uhonmora soil gave exchangeable potassium below the critical value of 0.3 cmol/kg required for coffee. The exchangeable Ca^{2+} of both locations fell below the critical value of 5 cmol/kg required for coffee growth. Again, at both locations, the exchangeable Mg^{2+} was inadequate for coffee production. Obatolu [24] earlier observed the general low Mg^{2+} nutrient content of coffee soils in southern part of Nigeria. The low nutrient contents of the soils implied the need for external input of nutrients in order to meet the requirements for optimal coffee growth. It is obvious that the soils of both Idi-Ayunre and Uhonmora were inherently low in fertility and were therefore expected to show positive response to soil amendment.

Predominant weed species observed in the plots are indicated in Table 2. The weeds were more of annual broad leaf weeds than grasses and sedges. Weed incidence was more prevalent in Idi-Ayunre than in Uhonmora. This might probably be as a result of the fact that Idi-Ayuunre was in Rain Forest zone with

Table 1. Physical and chemical soil properties of the experimental sites.

Soil Properties	Idi-Ayunre	Uhonmora
pH (H_2O)	6.2	5.2
% Organic carbon	0.75	0.84
% Total Nitrogen	0.07	0.09
Available P (mg/kg) Soil	7.40	7.15
Exchangeable K (cmol/kg) Soil	0.42	0.05
Exchangeable Ca (cmol/kg) Soil	2.45	2.65
Exchangeable Mg (cmol/kg) Soil	0.03	0.04
Exchangeable Na (cmol/kg) Soil	0.01	0.02
% Sand	81.60	78.8
% Clay	10.0	12.0
% Silt	8.40	9.2
Soil Classification	Alfisol	Ultisol

Table 2. Common weed species present at the experimental sites and their level of occurrence.

Weed species	Level of infestation			
	Idi-Ayunre		Uhonmora	
	2012	2013	2012	2013
Broad leaf weeds				
Euphorbia hirta L.	++	+	+	+
Euphorbia Heterophylla L.	++	++	++	++
Talinum triangulare (Jacq) Wild	+	++	++	++
Tridax procumbens L.	+	+	+	+
Ancanthospermum hispidum DC	++	++	++	++
Aspillia Africana (Pers) CD Adams	+++	++	++	++
Chromolaena odorata (L.) R.M. King and Robinson	+++	++	+++	++
Amaranthus viridis L.	++	++	+	+
Solanum nigrum L.	+	+	+	+
Grasses				
Cynodon dactylon (L.) Prs	+	+	+	+
Eleusine indica Gaertn	+	+	+	+
Panicum maximum Jacq	++	++	++	+
Chloris pilasa (Scham)	+	+	+	+
Sedges				
Cyperus rotundus L.	+	+	+	+
Cyperus esculentum L.	+	+	+	+
Cyperus deformis L.	+	+	+	+

+++ = High occurrence (60% - 90%); ++ = Moderate occurrence (40% - 59%); + = Minor occurrence (1% - 39%); - = Nil (absent).

more rains, while Uhonmora was in Derived Savanna. Also, there was less weed infestation in the second year compared to the first year in both locations. The higher vegetative growth of coffee and oil palm in the second year might be responsible for this. This shows that weed infestation might have constituted a major set-back to coffee production in early stage of field establishment, especially before the canopy closed. This is in consonance with CRIN [13] which found out that weed constituted the greatest problem of coffee production during the early year of field establishment before they formed sizeable canopy. It was also reported that weed was the commonest agronomic problem in coffee on the field [14].

Figure 2 shows the weed biomass at both locations. The highest weed biomass was recorded in the control treatment followed by Avenue with the least in Hollow square arrangement. This suggests the exposure of the ground surface of control treatment to more insolation. The significant less weed biomass in the hollow square arrangement plots suggests lesser weed incidence and lower labour

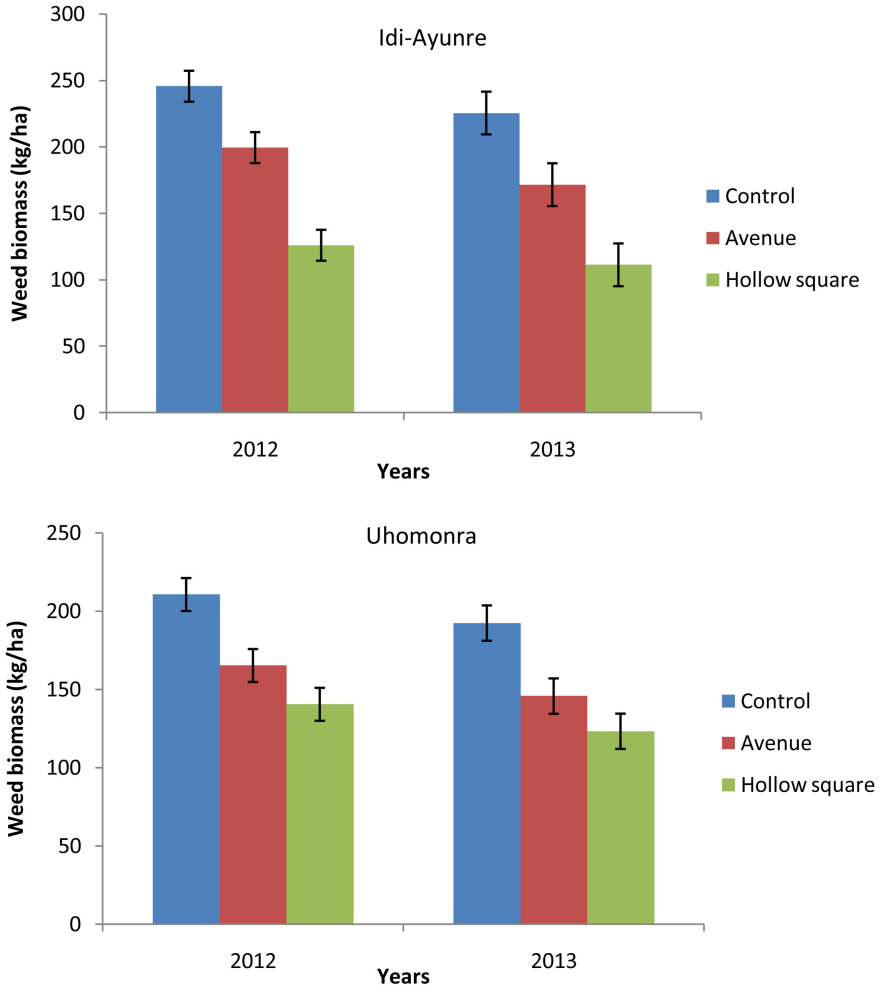

Figure 2. Effects of avenue and hollow square arrangements of coffee intercropped with oil palm on weed biomass at Idi-Ayunre and Uhonmora.

requirement for weeding compared to the control plots. This also implies that coffee/oil palm in Hollow square arrangement is a better cropping system than other treatments. This agrees with the earlier work of Adeyemi [25] that reported appropriate intercropping system of food crop combinations that would increase labour efficiency in coffee production. It also corroborates Famaye [16] who reported that coffee/plantain farming system suppressed weed growth. Similarly, Santos *et al.* [20] had reported a reduced weed infestation in coffee intercrop with herbaceous legumes. This underscores the significance of intercropping system in the control of weed in coffee farms.

The plant height and leaf area of coffee are shown in **Table 3** and **Table 4** respectively. Coffee in Hollow square was higher in plant height as well as leaf area than other treatments, although the difference was not significant ($P < 0.05$). The least incidence of weed under coffee Hollow square and the consequent less competition from weeds for plant nutrients might have made nutrients more available for the coffee under this treatment, thus leading to better growth. The least growth was recorded in the control. The higher plant height and leaf area of

Table 3. Mean plant height (cm) of coffee intercropped with oil palm in hollow square and avenue arrangements.

Location	Treatments	Months after transplanting							
		3	6	9	12	15	18	21	24
Idi-Ayunre	Coffee sole (Control)	20.1	30.0	39.0	43.1	47.2	49.7	58.3	70.7
	Avenue arrangement	19.1	27.0	43.4	45.2	49.7	50.9	60.0	75.3
	Hollow square arrangement	19.7	27.4	43.5	47.0	50.2	53.9	64.2	81.0
	Mean	20.0	28.1	42.1	45.1	48.5	51.7	60.8	75.7
	LSD ($P < 0.05$)	8.99	4.48	9.95	2.24	3.01	7.98	7.78	12.02
Uhonmora	Coffee sole (Control)	15.7	22.0	30.1	35.6	39.9	42.3	47.4	52.5
	Avenue arrangement	16.3	22.1	30.0	38.5	40.8	44.6	50.1	57.2
	Hollow square arrangement	15.5	24.3	38.1	42.7	45.5	50.2	57.5	63.4
	Mean	15.8	22.8	33.4	38.9	42.7	45.7	51.7	57.6
	LSD ($P < 0.05$)	1.03	3.23	10.38	8.86	7.47	10.07	12.98	18.31

Table 4. Mean leaf area (cm^2) of coffee intercropped with oil palm in avenue and hollow square arrangements.

Locations	Treatments	Months after transplanting							
		3	6	9	12	15	18	21	24
Idi-Ayunre	Coffee sole (Control)	74.1	82.0	86.4	105.2	116.0	119.7	157.7	140.2
	Avenue arrangement	73.0	82.1	87.8	110.3	121.5	130.3	142.6	149.0
	Hollow square arrangement	79.0	87.7	93.5	117.9	130.3	141.5	132.5	164.1
	Mean	75.4	83.9	89.2	111.1	122.6	130.5	144.0	151.1
	LSD ($P < 0.05$)	7.93	8.10	9.34	15.87	17.91	27.6	30.81	30.01
Uhonmora	Coffee sole (Control)	64.2	73.6	90.3	99.5	113.2	120.3	128.5	140.3
	Avenue arrangement	64.1	75.5	97.8	105.3	119.0	128.1	134.7	148.7
	Hollow square arrangement	64.5	78.0	105.1	116.4	125.3	137.6	145.4	159.1
	Mean	64.3	75.7	97.7	109.1	119.2	128.7	136.2	149.4
	LSD ($P < 0.05$)	0.52	4.48	18.37	21.32	15.02	21.51	72.22	23.38

coffee in Hollow square arrangement than in the control confirms the finding of Obatolu *et al.* [14] on the possibility of intercropping coffee with other crops.

4. Conclusion and Recommendations

The Hollow square arrangement of growing coffee with oil palm was found superior to Avenue arrangement and coffee sole cropping as it enhanced the growth of coffee as well as reduced weed infestation in coffee plantation. This Hollow square arrangement appears to be more profitable and could be recommended to Robusta coffee farmers in Nigeria.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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