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RESEARCH ARTICLE

SOIL CONSERVATION, NUTRIENT ENRICHMENT, AND PEST CONTROL USING *ALLIUM CEPA* AND *ALLIUM SATIVA* IN A LONG-TERM WHITE-CURL GRUB (*PHYLLOPHAGA SPP*) LARVA INFESTED CASSAVA FARMLAND

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ABSTRACT

Small-holder cassava farmers in Okwusonwu-atanga in Ikpo-Obibi have since more than 40 years ago been suffering from crop attack by the white curl grub (*Phyllophaga spp.*, Coleoptera: Scarabaeidae) pests. Several attempts have been made in the past by the farmers to find solution to the pest-invasion, but none was discovered yet. This study aimed at using the biological pest control method in the form of traditional application of the *Allium spp* and comparing the result with the dichlorodiphenyltrichloroethane (DDT) method. The study involved seven (7) treatments which included *Allium cepa*, *Allium sativa*, dichlorodiphenyltrichloroethane (DDT)-modern chemical pesticide, combination of *Allium spp*, A. *cepa* + DDT, A. *sativa* + DDT, and control which were arranged in a randomized complete block design with four replications. It was hypothesized that (i) the bio-traditional methods of soil conservation and pest control significantly decreased the impacts of *Phyllophaga spp,* and subsequently increased soil fertility and cassava yields as compared with the DDT and control treatments; (ii) combination of the *Allium spp* (*A.cepa* and *A.sativa*)showed better result in soil improvement and cassava yield than when the treatments were singly applied. Data were collected covering soil properties, cassava tuber and aboveground biomass yields, and the number of *Phyllophaga spp* larva per heap from the year 2010 to 2016. The result revealed that the combination of *A. cepa* and *A. sativa* treatment had the highest dry matter nutrient content in comparison with other treatments. DDT treatment showed very low yields in cassava tuber and aboveground biomass, and had relatively low C_{org} content than other treatments applied. Combined treatment with the *Allium spp* (CA) remarkably controlled the pests while, control treatment (Co) had the pests in abundance. This revealed that the application of *A. cepa* and *A. sativa* was not only economically and environmentally beneficial but was also highly productive. The study recommended that the local farmers be encouraged and emancipated on the regular use of *Allium spp* biological method of curl grub control instead of abandoning their lands or using DDT. Besides, further studies are needed to consolidate the findings of this result.

INTRODUCTION

Cassava (*Manihot esculenta Crantz*), is a tuber crop of 15 to 35 cm in length and a tuber diameter of 5 to10 cm. It is produced in almost all tropical countries and seldomly grows in degraded soils where almost nothing else can grow (Okudoh *et al*., 2014; Kuiper *et al*., 2007). Cassava can be harvested any time between8 to 24 months after planting (DAFF, 2013) depending on the variety. As a native to South America cassava has historically been used as human and animal feed source, and currently has many industrial applications (DAFF, 2013). Based on its hydrocyanic acid content, it is categorized into sweet cassava (directly consumed) and bitter cassava for making starch and other industrial purposes (TTDI,2013). Cassava tuber is organically rich in starch and carbohydrates but contains small amounts of protein, vitamins and minerals (Lancaster, 1982). The starch content of fresh cassava tuber was reported as 32.4% while the dry cassava contained 80.6% (Pandey, 2000). In Etche, Southern Nigeria, cassava cultivation is the primary farming activity of the local farmers who focused mainly on production for subsistent family and commercial purposes. The success achieved was limited mainly due to disease infestation caused by the leaf mosaic virus and bacterial blight. Although, through the introduction of genetic breeding and resistance genes with high yielding varieties of cassava, the International Institute of Tropical Agriculture (IITA) has successfully curbed the cassava leaf mosaic virus and bacterial blight (Okudoh *et al*., 2014).Cassava varieties that yield five times more tubers per hectare than the traditional cultivars were introduced (Babaleye *et al*., 1996), but the presence of Curl grubs (*Phyllophaga spp)* limits the crop production in Etche.

Curl grubs (*Phyllophaga spp)* belongs to the family of Coleoptera, Scarabaeidae. It has been the major pest of arable crops in Ikpo-Obibi community thus, rendering most land useless for any meaningful farming activities. The curl grub (white-maggot or white grub or *Phyllophaga spp*) is commonly called 'atanga' by the local farmers in the study area. *Phyllophaga spp* are the larvae of different species of beetle including the African Black Beetle, the black-headed pasture cockchafer, Christmas beetles and Scarab beetles (Minja *et al*, 1992; Evans *et al*., 1999). The *Phyllophaga spp* larvae feed on dead plant material, fresh roots and/or stems of many crops especially cassava. They are white or pale cream in color with a brown head and grayish end. They mature to about 2.5cm in length and are sometimes mistaken for witchetty grubs (*Endoxylaleucomochla*). It is their habit of curling up into a "C" shape that gives them their common name. As the curl grubs *(Phyllophaga spp)* feed, plants and lawns fail to perform well and often appear to need watering despite the ground still being moist, and it has been reported to be among the most destructive pests in in tropical and subtropical regions (Morón 1997; Carrillo-Benítez *et al*., 2013). During the warmer weather curl grub pests hatch new eggs while, older larvae move closer to the soil surface feeding more heavily on plant roots (Evans *et al*, 1999). Much stress is placed on the surviving plants after the pest infestation and coupled with the high temperature from the atmospheric insolation. Thus, the effects of the pests became intensified on all the parts of the plants especially the roots. The negative effects of the pests' activities are intensively unbearable by the rural farmers who have tried every locally known method as well as few modern control techniques that they could afford yet, found no solution to restoring their farmland from these invading pests. The study therefore aimed at evaluating the efficacy of *Allium spp* on *Phyllophaga spp* in comparison with synthetic DDT which has adverse effects on the environment and has been a common practice by the farmers.

MATERIALS AND METHODS

Study area: The study was carried out in Ikpo-Obibi community in Etche Local Government Area of Rivers State, Nigeria,- located on longitude 06° 05' E - 07° 14' E and latitude 04° 45' N - 05° 08' N. The rainy season lasts from April to October with a peak rainfall in July and August. The dry season starts from November and ends in March. The annual rainfall range in the four experimental years (2010, 2012, 2014, and 2015) was from 2000 mm to 3000 mm, and annual temperature ranging from 26.4°C to 38.6°C (SPDC, 1998). The area is a typical rainforest region with traces of mangrove and Freshwater swamp forests towards the south and in areas along the major rivers (Nwaogu, 2000). Ikpo-Obibi in Etche is a subsistent agrarian ethnic group in Rivers State and is situated on the eastern flank of the Niger Delta Region of Nigeria. The inhabitants engage in farming, palm wine tapping, fishing, logging, hunting, oil and sand mining (Ogbuagu and Ayoade, 2012). The study area has been abandoned without any active farming activities for the past 6-8 decades due to soil *Phyllophaga spp* invasion (figure 1). The pests destroy the development of any crop especially cassava, cultivated at the site from growing period to maturity stage, and leaving the rural farmers with little or nothing to be harvested. *Experimental Design, establishment of cassava plot, and data sampling:* The experiment consisted of seven (7) treatments which included *Allium cepa* (**C**), *Allium sativa* (**A**), D representing dichlorodiphenyltrichloroethane (DDT)-modern chemical pesticide; combination of *Allium spp* (CA),A. *cepa* + DDT (CD), A. *sativa* + DDT (AD), and control (**Co**) which were arranged in a randomized complete block design (RCBD) (Figure 2.) with four replications. The experiment was performed on a 2,500 m^2 field, and 80% of the entire area was used for planting while, the remaining percentages included the borders around the whole planting area. Each plot was 5 m x 10 m (50 m^2) and separated by 1m buffer zones. Land preparation took place in 2009, and the experiment was performed in2010, 2012, 2014 and 2016 while, 2011, 2013, and 2015 were the land fallow periods introduced to enable the soil regain fertility since no artificial fertilizer was applied. The land was manually cleared observing the local tradition of slash and burn. Subsequently, heaps of 40-50cm high and 50-60cm in diameter were prepared between January and February before the first rainfall of the year. The new NR8082 cassava high yielding variety from the International Institute of Tropical Agriculture (IITA), Ibadan-Nigeria was used. Cassava cuttings were taken from stems that were healthy and free from diseases. The stems were cut into segments of 20 to 25 cm in length while, sliced red-onions and garlic bulbs, and DDT pesticides were applied into and around the made heaps before cultivating in March. A sizeable bulb of onions weighing about 20 g was sliced and used for 5 heaps in the C-treatment. Similarly, a sizeable bulb of garlic (containing 8-12 cloves) was sliced and used for 5 heaps in the A-treatment, and in the combined treatment of onions and garlic (CA), a bulb each of onions and garlic was used for 10 heaps (CA). A 4 liter of the DDT pesticide was mixed with about 15 – 20 liters of water, and this was done as to reduce the high concentration and prevent damage on the stems. For the D, CD, and AD treatments, a liter of the mixture covered between 45-50 heaps. And this was sprinkled in/around the heaps and on the stems using a locally made sprinkling-can. The stems were planted at vertical position between 15 to 20 cm depth in continuous row heaps, and with 70 cm between rows and 50 cm between plants. A total of 10,000 stem stand were planted per hectare. Weeding was done once a month using the local weeding hoes and cutlasses in all the plots.

Figure 1. White-Curl grub (*Phyllophagaspp*) larva

Three harvest frequencies were applied including two cutting time at 5, and 10 months; and a single harvest at root-tuber harvesting.

Soil chemical properties: Soil samples were randomly collected twice (in July and December) from each plot in every experimental year (2010, 2012, 2014, and 2016) as a mixture

Block I								**Block III**						
C	A	CA	D	CD	AD	Co		CD	D	C	Co	AD	A	CA
Co	C	A	CA	D	CD	AD		C	Co	D	CA	A	CD	AD
D	CD	AD	Co	C	A	CA		AD	CD	A	C	Co	CA	D
CA	D	CD	AD	Co	C	A		Co	AD	CA	A	C	D	CD
A	CA	D	CD	AD	Co	C		A	C	CD	D	CA	AD	Co
CD	AD	Co	C	A	CA	D		D	CA	Co	AD	CD	C	A
AD	Co	C	A	CA	D	CD		CA	A	AD	CD	D	Co	C
Block II								**Block IV**						
A	CA	D	CD	AD	Co	C		Co	C	A	CA	D	CD	AD
D	CD	AD	Co	C	A	CA		CD	AD	Co	C	A	CA	D
CA	D	CD	AD	Co	C	A		A	CA	D	CD	AD	Co	C
CD	AD	Co	C	A	CA	D		C	A	CA	D	CD	AD	Co
AD	Co	C	A	CA	D	CD		CA	D	CD	AD	Co	C	A
C	A	CA	D	CD	AD	Co		AD	Co	C	A	CA	D	CD
Co	C	A	CA	D	CD	AD		D	CD	AD	Co	C	A	CA

Treatment abbreviations: *Allium cepa*= C; *Allium sativa* = A; Modern pesticide (DDT) = D; Combination of *Allium spp* (A.*cepa* and A.*sativa*) = CA; Combination of A.*cepa* and DDT = CD; Combination of A. *sativa* and DDT = AD; Control treatment = Co

Figure 2. Experimental design of the treatments

of four individual subsamples from the upper 15cm layer of the soil. The soil samples were collected using a graduated auger of 7 cm diameter and taken to the laboratory where they were air-dried and visible biomass residues, roots and other organic debris removed. Finally, the samples were ground in a mortar to pass a 2mm sieve before taking to the laboratories for analysis. The soil samples were analyzed for total organic carbon (C_{org}) using the Walkely-Black wet oxidation method (Nelson and Sommers, 1982). pH was determined in a 0.2 mol KCl Solution; Total Nitrogen (N_{tot}) was measured using micro-Kjeldahl procedure (Bremner and Mulvaney, 1982). Plant-available P and K concentrations were extracted using Mehlich III Solution (Mehlich, 1984) regent, and determined using ICP-OES while, extractable sulphate sulphur was determined by the procedure of Tabatabai (1974). Ca and Mg concentrations were derived using Atomic Absorption Spectrometer. The soil properties at the site were sampled before the commencement of theexperiment and the result was 0.91 g kg^{-1}Ntot, 7.6 mg kg^{-1}P, 11.2 mg kg^{-1}K, 21.03 mg kg^{-1}Ca, 14.94 mg kg^{-1}Mg, 21.47 mg kg^{-1}S, 6.70 g $kg^{-1}C_{org}$, and 6.64 pH. The mean of four samples from each experimental plot formed the start analysis.

Yield: Cassava tubers were harvested after 10 months (in late December) at physiological maturity. At twice cutting in July and early December, the aboveground biomass (AGB) including stems, leaves, flowers and seeds were collected from 4m x 4m ($16m^2$) selected at random from each treatment plot. The cutting was performed between 7.00 hours - 9.00 hours to avoid fluctuations in hydrogen cyanide (HCN) content, which tend to occur later during the day due to the wide variation in temperature from solar radiation (Stochmal and Oleszek, 1997). The weight of the samples was determined in the field using a digital scale, and the subsamples were oven dried at 75^0 C to determined dry matter biomass. The concentrations of the chemical nutrients were determined after digestion in aqua regia by inductively coupled plasma optical emission spectrometry (ICP-OES).

Data analysis: Dataon soil chemical properties, cassava yields, in relation to the soil curl grubs (white-maggot) pest, were analysed using a repeated measure ANOVA and a one-way ANOVA followed by a post hoc comparison-Tukey HSD test. The relationships between nutrients in the soil and in the plant biomass were analyzed by regression analysis. All analyses were done using the IBM SPSS Statistics Version 20 (IBM, 2011). A redundancy Analysis (RDA) followed by a Monte Carlo Permutation test with 999 permutations in the Canoco version 5.0 (Ter Braak and šmilaner, 2012) was used to evaluate the effect of treatment on soil and biomass chemical properties. A biplot ordination diagram was produced by employing the Cano Draw program which enabled the presentation and visualization of the RDA results of the experiment.

RESULTS

Soil chemical properties and cassava biomass nutrients: The results of the mean soil nutrient concentration under the different treatments are shown in Table 1. Combination of A. *cepa* and A. *sativa* (CA) treatment recorded the highest concentrations of soil nutrients except for S as compared with other treatments. The CA treatment had the highest mean content (55.03 mg kg^{-1}) for Ca. P showed the lowest mean concentration under the different treatments, and this ranged from 6.16 mg kg^{-1} to 8.77 mg kg^{-1}. The mean content for C_{org} was substantially high under the CA treatment as compared with the other treatments. Modern pesticide, DDT (D)treatment had the lowest mean concentration of C_{org}. Across treatments applied, N_{tot} revealed a marginally significant difference (p = 0.046) while, pH and P content did not show any significant difference. The concentrations of K, Ca, Mg, S, and C_{org} recorded significant differences. The result of the RDA (Figure 3). Revealed that the first and the second ordination axes and all the ordination axes for soil chemical properties and treatments were significant ($p < 0.001$). The percentage of explained variability by the first ordination axis was 56.7%. The concentrations of P, K, Ca, C in the soil, and concentrations of N, C, K, Ca in the plants were associated with CA, C, and A treatments while, Mg concentrations in soil and biomass were related to AD treatment. On the other hand, N and S in the soil tend to be more associated with CD and D treatments respectively. In relation to the aboveground dry matter (DM) biomass nutrient concentration. CA treatment recorded the highest nutrient content (except for Mg) as compared with other treatments (Figure 4). Co treatment had the lowest nutrient concentration under the different treatments. All the nutrients monitored showed significant differences ($p < 0.05$) under the different treatments.

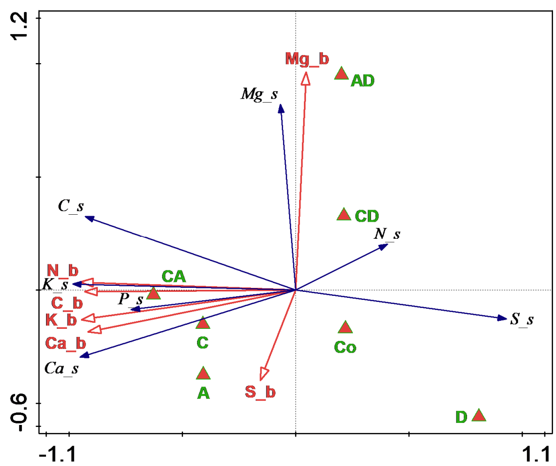

Figure 3. Biplot diagram showing the results from the RDA produced via CanoDraw program showing the relationships between the soil chemical properties, cassava biomass nutrients in relation to the treatments. Nutrient concentrations in the soil are indicated as Ca_s, K_s, P_s, Mg_s, S_s, N_s, and C_s; while, nutrient concentrations in the cassava biomass are indicated as Ca_b, K_b, P_b, Mg_b, S_b, N_b, and C_b; The treatment abbreviations (C, A, CA, D, CD, AD, and Co) are explained in Figure 2.

Cassava yields and pests: Treatments D, CD, AD, and Co were significant while, treatments C, A, and CA revealed no significant differences in cassava tuber yield between the years monitored (Figure5). The CA treatment had the highest mean tuber yield which was substantially higher than the record for Co treatment for the 4 years of study. The annual total (mean) yield (t ha^{-1}) for cassava tuber in 2010, 2012, 2014, and 2016 were 158.7 (22.67), 164.06 (23.44), 181.55 (25.94), and 164.05 (23.43) respectively.

Table 1. Soil chemical properties under the different treatments in 2010-2016

Treatment	P	K	Ca	Mg	S	PH	N_{tot}	C_{org}
			(mg kg-1)				(g kg-1)	
C	8.61±1.1	18.72±3.5a	39.45±6.2b	11.79±1.7d	15.64±3.3d	6.79±0.2	2.44±0.3c	17.29±3.4b
A	8.77±2.4	17.9±4.1a	41.17±7.5ab	9.43±1.1e	17.72±3.9c	6.82±0.3	2.21±0.1c	18.06±4.1b
CA	7.32±1.7	19.36±6.3a	55.03±7.6a	13.61±2.2c	11.33±1.5e	6.65±0.2	2.75±0.1b	22.73±5.7a
D	6.16±1.2	4.08±0.5c	10.99±1.1e	9.07±0.6e	27.5±3.1a	5.6±0.1	3.28±0.4a	4.02±0.8f
CD	7.09±2.0	8.44±1.8b	16.18±2.3d	13.14±3.3c	20.01±2.5b	6.75±0.5	2.92±0.2ab	11.66±1.9d
AD	7.25±2.8	9.63±2.1b	12.64±1.4e	17.56±5.1a	19.96±2.1b	6.69±0.1	2.85±0.3ab	14.07±2.2c
Co	7.97±1.9	10.28±1.7b	20.11±3.0c	15.23±3.8b	22.47±5.5b	6.88±0.4	1.89±0.0d	7.21±2.0e
p-value	0.318	0.004	0.015	< 0.001	< 0.001	0.074	0.046	< 0.001

In relation to the AGB mean yield, CA treatment was about five times more than Co treatment for the study period (Figure 6). All the treatments (except treatments D and Co) significantly differ between the years in relation to cassava DM biomass yield. Consistently with the tuber yield, 2014, had the highest biomass yield under the different treatments. More than 80% of the soil curl grub pests were found in cassava cultivation heaps under the control treatment while, the heaps in other treatments had less than 20% (Table 2). In terms of years, 2010 recorded the average number of 10 curl grubs was more than the record in 2014. Strongly significant relationships were observed between nutrient concentrations in the soil and in above ground biomass (AGB) for most of the elements studied (Table 3).

DISCUSSION

Soil chemical properties and cassava biomass nutrients concentrations: The combination of the *Allium spp* (A. *cepa* and A. *sativa*) produced a remarkable result by reducing the impacts of the pests and atmospheric deposition and improving soil nutrients as compared with other treatments. This could be attributed to the presence of the crop residues which decomposed and added green manures to the soil (Douiri *et al*., 2013). Several studies have emphasized the increase in soil fertility and pest control by the application of organic manures such as *Alliumspp* (Mallek *et al*., 2007; Denloye *et al*., 2000). The crop residues boosted the activities of the soil micro-organisms which consequently increased the SOC, and SOM contents. Integrating *A. cepa* with DDT treatments, and *A. sativa* with DDT did not enhance soil nutrients except for the concentration of S, Ca, and Mg. Though the application of the modern chemical pest control- dichlodiphenyltrichloroethane (DDT) helped in getting rid of the curl grubs yet, the soil microorganisms were adversely affected. The chemical composition of DDT might have influenced the potential of the *Allium spp* from enriching the soil. Past authors have reiterated the negative effects of using chemicals and pesticides such as DDT for pest control (Clark 1983). Apart from killing the living soil organisms, larger percentage of the plants essential elements are destroyed by applying DDT into the agricultural soils (Megharaj *et al*., 2000). The study site is a region experiencing severe industrial activities such as crude-oil mining, gas flaring and atmospheric deposition. The addition of DDT into the soil coupled with the industrial pollution increased soil contamination. The N content was unexpectedly high under the D treatment. This could probably be explained by increased S which consequently increased N because biological N_2 fixation and photosynthesis are processes supported by increased S (Lucht and Lambia, 2012). However, the contents of P. K, Ca, and Mg were low under the D treatment.

This might be attributed tothe absence of mycorrhizas, low mineralization, and enrichment of Fe and Al oxides. The Co treatment recorded poor nutrient because of the curl grub pests which decreased the SOC since they feed not only on the crops but also on other essential soil microorganisms such as earthworms. Similarly, CA treatment had higher content of C_{org}, N, P, K, and Ca as compared with other treatments. This could be explained by the green manure supplements from the *Allium spp*. Mg concentration was relatively low in the plant in CA, C, and A treatments; and higher Ca and K might be responsible for the low Mg content. The N content in cassava bio mass was relatively low under the D treatment as compared with other treatments. This could be explained by the low pH which decreased the plants use of N under the D treatment (Lucht and Lambia, 2012).

Yields and pests: The higher yield of tuber and AGB were expected under CA treatment in comparison with other treatments. Improved soil nutrients including SOC and SOM consequently increased the cassava yield under the CA treatment. The Co treatment recorded poor yields because the soil curl grubs could not allow the crops to grow, develop, and produce to their capacities (Minja *et al*., 1992). The remarkable high yield found in 2014 might be related to the favorable high rainfall experienced. In addition to favoring the crops, increased rainfall amount was a threat to the pests (Evans *et al*, 1999). For example, only about 15% of the total number of the curl grub pests was discovered in 2014. Based on this, 2014 had the highest tuber and biomass yields when compared to other experimental years.

Conclusion

High Sulphur content was recorded under the D treatment in comparison with other treatments. This might be attributed to the chemical composition of the pesticide. On the other hand, D treatment showed very low C_{org} content as compared with other treatment regimes. The inability or unavailability of the soil microorganism due to the toxicity in this plot might be a reason for low C_{org} content. The nutrient contents in the aboveground biomass significantly differ under the different treatments except for Mg. The concentrations of K and/or Ca could have affected the Mg content. CA treatment had the highest dry matter nutrient content in comparison with the results from all the treatment plots. The decompositions of the *Allium spp* might have enriched the soil nutrients. In the four years of study, C, A, and CA treatments showed no significant differences in the cassava tuber yields between the years whereas, the D, CD, AD, and Co treatments significantly differ. C, A, and CA treatments recorded the highest biomass production when compared with either the Co or the DDT treatments. The relationships between nutrient concentrations in the soil and in AGB revealed that K, Ca, S, N, and C concentrations were significant at $p < 0.05$. During the experimental years, the combined treatment with the *Allium spp* (CA) remarkably controlled the pests while, the unmanaged treatment (Co) had the pests in abundance. This revealed that the application of A. *cepa* and A. *sativa* was not only economic and environmentally beneficial but also highly productive. The study recommended that the local farmers should be encouraged and emancipated on the regular use of this biological method of curl grub control instead of either using DDT or abandoning their lands. Besides, further studies are needed to consolidate the findings of this result.

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