

Evaluating Changes in Fertility Status of an Alfisol and Cassava (Manihot esculenta Crantz) Performance under Different Weed Species in a Cassava Field in Southwestern Nigeria

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Abstract
Although, empirical evidence from many parts of the world indicates that, vegetation (plants) can ameliorate soil conditions on lands, once badly degraded, and hence, improving productive potential of such lands. However, in Southwestern Nigeria, there is hitherto, dearth of published scientific data and information on the relative effectiveness of weed species in ameliorating poor soil conditions, with resultant improved agricultural productivity of such soils. To this end, this study was designed to assess ameliorating effects of certain weed species on a severely degraded Alfisol and yield performance of cassava (*Manihot esculenta* Crantz). The study was carried out at the Teaching and Research Farm of the Ekiti State University, Ado - Ekiti, Ekiti State, Nigeria, during 2011 and 2012 cropping seasons. The experiment was laid out in a randomized complete block design with three replicates. The different weed species included: *Tithonia diversifolia* (TD); *Pueraria phaseoloides* (PP); *Chromolaena odorata* (CO); *Panicum maximum* (PM); *Aspilia Africana* (AA); and weed – free (WF), which served as the control treatment. The results obtained indicated existence of significant (P = 0.05) differences among the weed species as regards their ameliorating effects on nutrient status of a degraded Alfisol, cassava root yield and yield components. At the end of 2011 cropping season, weed species significantly increased soil organic carbon (SOC) from 0.33 g kg^{-1} for WF to 0.70, 0.62, 0.77, 0.40 and 0.55 g kg^{-1} for TD, PP, CO, PM and AA, respectively. Similarly, at the end of 2012 cropping season, weed species significantly increased SOC from 0.22 g kg^{-1} for WF to 0.74, 0.67, 0.83, 0.45 and 0.60 g kg^{-1} for the respective TD, PP, CO, PM, and AA. At the end of 2011 cropping season, weed species significantly increased total N from 0.18 g kg^{-1} for WF to 0.36, 0.49, 0.42, 0.25 and 0.31 g kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2012 cropping season, weed species significantly increased total N from 0.13 g kg^{-1} for WF to 0.40, 0.56, 0.48, 0.30 and 0.35 g kg^{-1} for the respective TD, PP, CO, PM, and AA. Means of cassava root yield data across the two years of experimentation indicated that, weed species significantly reduced cassava root yield from 9.23 t ha^{-1} for WF to 4.27, 7.31, 5.61, 4.57 and 5.37 t ha^{-1} for TD, PP, CO, PM and AA, respectively.
Keywords: Cassava, field, fertility, status, species, weed.

Introduction

Weeds constitute one of the most complex crop pests, which Nigerian farmers, like all farmers in developing countries have to contend with. Yield reductions of crops in Nigeria, due to weed interference can be as high as 40 – 90% (Akobundu and Agyakwa, 1987).

Previous studies (Alalade, 2010; Atilola, 2012; Cantillo, 2014) have indicated that, the extent of weed – crop competition, depends on a variety of factors, including crop type (cultivar), seeding rate, spatial arrangement of crops, plant architecture, cropping patterns, weed density, tillage and soil fertility.

Cassava (*Manihot esculenta* Crantz) is so sensitive to weed interference, especially at the early stages of growth, that its root yield can be reduced by as much as 40 – 70% (Atilola, 2012; Cantillo, 2014). While cassava can, under favourable conditions, recover from damage, caused by insect pests and diseases, it generally succumbs to early weed interference. Slow growth rate or slow initial development makes all cassava cultivars susceptible to weed interference during the first 10 – 12 weeks of growth (Aka, 2012; Anda; 2012; Dios, 2014). Yield components of cassava, most affected by weeds are tuber number and tuber weight (Aka, 2012; Atilola, 2012). Although, competition from weeds occurs at all periods of growth after rooting, however, the most damaging effects of weeds on cassava occurs during early canopy formation and in the third month after planting, when tuberization commences (Anda, 2012; Cantillo, 2014). Cassava competes well with weeds, once canopy is fully developed. The ability of cassava to compete with weeds depends, to some extent, on how long after planting the crop stays weed – free before the canopy completely shades the ground (Cantillo, 2014).

In order to minimize high cassava root yield reduction, associated with weed interference, weeding operations in cassava, should be properly timed in such a way they will coincide with the most critical stage in its vegetative growth phase, when it is most vulnerable to weed interference (Alalade, 2010; Olonitola, 2014). Alalade (2010); Singh (2011) and Olonitola (2014) recommended three properly spaced hand weedings, at 3, 8 and 12 weeks after planting, as delayed weeding may result in a significant reduction in cassava root yield.

Although, in Southwestern Nigeria, many studies had been conducted on evaluation of the efficacy of different weed management options in cassava, with a view to minimizing cassava - weed competition, and hence, minimizing cassava root yield reduction, associated with weed interference. However, in view of the paucity of published scientific data and information on the ameliorating effects of *Tithonia diversifolia*, *Pueraria phaseoloides*, *Chromolaena odorata*, *Panicum maximum*, and *Aspilia Africana* on fertility status of a degraded Alfisol and cassava root yield in Southwestern Nigeria, there is, therefore, a dire need for critical assessment of ameliorating effects of *Tithonia diversifolia*, *Pueraria phaseoloides*, *Chromolaena odorata*, *Panicum maximum*, and *Aspilia Africana* on fertility status of a degraded Alfisol and cassava root yield performance. Consequent upon this, a two - year - trial was designed with a view to determining the ameliorating effects of *Tithonia diversifolia*, *Pueraria phaseoloides*, *Chromolaena odorata*, *Panicum maximum*, and *Aspilia Africana* on nutrient status of a degraded Alfisol and root yield of cassava.

Materials and Methods

Study site: An experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2011 and 2012 cropping seasons. The soil in the study site belongs to the broad group Alfisol (SSS, 2002). The soil was highly leached, with low to medium organic matter, deep red – clay profile, with top sandy loam texture. The study site had been under continuous cultivation of a variety of arable crops, among which were cassava, maize, melon, cocoyam, sweet potato, prior to the commencement of this study.

Collection and analysis of soil samples: Prior to planting, ten core soil samples, randomly collected from 0 – 15 cm soil depth, were bulked inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. At the end of each year cropping, another set of soil samples was collected in each treatment plot and analyzed. The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples and residues of the weed species were analyzed in accordance with the soil and plant analytical procedures, outlined by the International Institute of Tropical Agriculture (IITA) (1989).

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The different weed species included: *Tithonia diversifolia* (TD); *Pueraria phaseoloides* (PP); *Chromolaena odorata* (CO); *Panicum maximum* (PM); *Aspilia Africana* (AA); and weed – free (WF), which served as the control treatment. Each plot size was 3 m x 3 m.

Planting, weeding, collection and analysis of data: Planting of cassava was done on March 1 and March 3 in 2011 and 2012, respectively. Stem – cuttings (20 cm long each) of early maturing cassava variety Tropical Manihot Series (TMS) 30572, obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted at 1 m x 1 m (10,000 cassava plants ha^{-1}). Weeding was carried out manually in the weed – free plots (control), at 3, 6, 9, 12 and 15 weeks after planting (WAP), using a hoe, while in the weedy plots (plots of cassava – weed species), weeds, other than *Tithonia diversifolia*, *Pueraria phaseoloides*, *Chromolaena odorata, Panicum maximum*, and *Aspilia Africana* (where they occurred), were carefully and completely hand - removed in the weedy plots.

At harvest (12 months after planting, MAP), data were collected on cassava root yield and yield components. All the data were subjected to analysis of variance, and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Results

Chemical properties of an Alfisol prior to 2011 cropping season.

Table 1: The chemical properties of an Alfisol prior to 2011 cropping season.

Soil properties	Values
pH	5.6
Organic carbon ($g\ kg^{-1}$)	0.90
Total nitrogen ($g\ kg^{-1}$)	0.60
Available phosphorus ($mg\ kg^{-1}$)	0.66
Exchangeable bases ($cmol\ kg^{-1}$)	
Potassium	0.58
Calcium	0. 62
Magnesium	0.60
Sodium	0.55
Exchangeable Acidity	0.32
Effective Cation Exchangeable Capacity (ECEC)	2.67

Table 2: Nutrient composition of residues of the weed species.

	Values

Parameters		TD	PP	CO	PM	AA
Organic carbon	(g kg^{-1})	0.97	0.84	1.10	0.70	0.69
Total nitrogen	,,	0.62	0.78	0.72	0.40	0.56
C/N ratio		1.56	1.08	1.53	1.75	1.23
Phosphorus	,,	0.81	0.68	0.74	0.52	0.61
Potassium	,,	0.68	0.53	0.58	0.40	0.45
Calcium	,,	0.56	0.48	0.51	0.42	0.44
Magnesium	,,	0.63	0.51	0.48	0.42	0.51
Sodium	,,	0.53	0.52	0.40	0.37	0.48

TD = *Tithonia diversifolia*; PP = *Pueraria phaseoloides*; CO = *Chromolaena odorata*; PM = *Panicum maximum*; AA = *Aspilia Africana*.

Changes in nutrient status of a degraded Alfisol at the end of 2011 and 2012 cropping seasons.

Tables 3 and 4 show chemical properties of a degraded Alfisol as affected by weed species at the end of 2011 and 2012 cropping seasons. At the end of 2011 cropping season, weed species significantly (P = 0.05) increased pH of Alfisol from 3.8 for WF to 9.2, 8.6, 9.8, 7.4 and 8.0 for TD, PP, CO, PM and AA, respectively. Similarly, at the end of 2012 cropping season, weed species significantly increased pH of Alfisol from 3.3 for WF to 9.6, 9.0 and 10.4, 8.0 and 8.5 for the respective TD, PP, CO, PM and AA.

At the end of 2011 cropping season, weed species significantly increased soil organic carbon (SOC) from 0.33 g kg^{-1} for WF to 0.70, 0.62, 0.77, 0.40 and 0.55 g kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2012 cropping season, weed species significantly increased soil organic carbon (SOC) from 0.22 g kg^{-1} for WF to 0.74, 0.67, 0.83, 0.45 and 0.60 g kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2011 cropping season, weed species significantly increased total N from 0.18 g kg^{-1} for WF to 0.36, 0.49, 0.42, 0.25 and 0.31 g kg^{-1} for the respective TD, PP, CO, PM and AA. Similarly, at the end of 2012 cropping season, weed species significantly increased total N from 0.13 g kg^{-1} for WF to 0.40, 0.56, 0.48, 0.30 and 0.35 g kg^{-1} for the respective TD, PP, CO, PM and AA.

At the end of 2011 cropping season, weed species significantly increased available P from 0.20 mg kg^{-1} for WF to 0.52, 0.46, 0.59, 0.32 and 0.40 mg kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2012 cropping season, weed species significantly increased available P from 0.14 mg kg^{-1} for WF to 0.56, 0.50, 0.65, 0.38 and 0.45 mg kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2011 cropping season, weed species significantly increased exchangeable K from 0.13 cmol kg^{-1} for WF to 0.45, 0.38, 0.50, 0.26 and 0.32 cmol kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2012 cropping season, weed species significantly increased exchangeable K from 0.10 cmol kg^{-1} for WF to 0.47, 0.40, 0.52, 0.29 and 0.34 cmol kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2011 cropping season, weed species significantly increased exchangeable Ca from 0.15 cmol kg^{-1} for WF to 0.50, 0.44, 0.57, 0.30 and 0.36 cmol kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2012 cropping season, weed species significantly increased exchangeable Ca from 0.12 cmol kg^{-1} for WF to 0.52, 0.47, 0.60, 0.34 and 0.40 cmol kg^{-1} for TD, PP, CO, PM and AA, respectively.

At the end of 2011 cropping season, weed species significantly increased exchangeable Mg from 0.17 cmol kg^{-1} for WF to 0.48, 0.43, 0.55, 0.28 and 0.34 cmol kg^{-1} for the respective TD, PP, CO, PM and AA. At the end of 2012 cropping season, weed species significantly increased exchangeable Mg from 0.14 cmol kg^{-1} for WF to 0.51, 0.46, 0.58, 0.31 and 0.37 cmol kg^{-1} for the respective TD, PP, CO, PM and AA. At the end of 2011 cropping season, weed species significantly increased exchangeable Na from 0.11 cmol kg^{-1} for WF to 0.43, 0.36, 0.48, 0.23 and 0.31 cmol kg^{-1} for TD, PP, CO, PM and AA, respectively. At the end of 2012 cropping season, weed species significantly increased exchangeable Na from 0.09 cmol kg^{-1} for WF to 0.45, 0.39, 0.51, 0.26 and 0.34 cmol kg^{-1} for TD, PP, CO, PM and AA, respectively.

Table 3: Chemical properties of a degraded Alfisol as affected by weed species at the end of 2011 cropping season.

Treatments (weed species)	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1}) K	Ca	Mg	Na
WF	3.8f	0.33f	0.18f	0.20f	0.13f	0.15f	0.17f	1.11f
TD	9.2b	0.70b	0.36c	0.52b	0.45b	0.50b	0.48b	0.43b
PP	8.6c	0.62c	0.49a	0.46c	0.38c	0.44c	0.43b	0.36c
CO	9.8a	0.77a	0.42b	0.59a	0.50a	0.57a	0.55a	0.48a
PM	7.4e	0.40e	0.25e	0.32e	0.26e	0.30e	0.28e	0.23e
AA	8.0d	0.55d	0.31d	0.40d	0.32d	0.36d	0.34d	0.31d

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). WF = weed free; TD = *Tithonia diversifolia*; PP = *Pueraria phaseoloides*; CO = *Chromolaena odorata*; PM = *Panicum maximum*; AA = *Aspilia Africana*.

Table 4: Chemical properties of a degraded Alfisol as affected by weed species at the end of 2012 cropping season.

Treatments (weed species)	pH	Org. C (g kg^{-1})	Total N (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases (cmol kg^{-1}) K	Ca	Mg	Na
WF	3.3f	0.22f	0.13f	0.14f	0.10f	0.12f	0.14f	0.09f
TD	9.6b	0.74b	0.40c	0.56b	0.47b	0.52b	0.51b	045b
PP	9.0c	0.67c	0.56a	0.50c	0.40c	0.47c	0.46c	0.39c
CO	10.4a	0.83a	0.48b	0.65a	0.52a	0.60a	0.58a	0.57a
PM	8.0e	0.45e	0.30e	0.38e	0.29e	0.34e	0.31e	0.26e
AA	8.5d	0.60d	0.35d	0.45d	0.34d	0.40d	0.37d	0.34d

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). WF = weed free; TD = *Tithonia diversifolia*; PP = *Pueraria phaseoloides*; CO = *Chromolaena odorata*; PM = *Panicum maximum*; AA = *Aspilia Africana*.

Cassava root yield and yield components: Table 5 shows cassava root yield and yield components as affected by different weed species at harvest. Means of cassava root yield data across the two years of experimentation indicated that, weed species significantly reduced cassava root yield from 9.20 t ha^{-1} for WF to 4.27, 7.31, 5.61, 4.57 and 5.37 t ha^{-1} for TD, PP, CO, PM and AA, respectively. Similarly, weed species significantly reduced cassava root length from 22.25 cm for WF to 11.31, 18.35, 14.25, 11.66 and 12.88 cm for TD, PP, CO, PM and AA, respectively. Weed species significantly reduced cassava root diameter from 18. 12 cm for WF to 10.52, 16.21 13.18, 10.22 and 11.37 cm for the respective TD, PP, CO, PM, and AA.

Table 5: Root yield and yield components of cassava as affected by weed species at harvest

Treatments (weed species)	Cassava root yield (t ha^{-1}) 2011	2012	Mean	Cassava root length (cm) 2011	2012	Mean	Cassava root diameter (cm) 2011	2012	Mean
WF	9.56a	8.90a	9.23	22.62a	21.88a	22.25	18.20a	18.04a	18.12
TD	4.20f	4.33f	4.27	11.21f	11.41f	11.31	10.47f	10.56f	10.52
PP	7.21b	7.40b	7.31	18.22b	18.47b	18.35	16.33b	16.48b	16.21
CO	5.50c	5.71c	5.61	14.11c	14.38c	14.25	13.26c	13.50c	13.18
PM	4.50e	4.63e	4.57	11.56e	11.76e	11.66	10.11e	10.32e	10.22
AA	5.33d	5.40d	5.37	12.82d	12.94d	12.88	11.30d	11.43d	11.37

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). WF = weed free; TD = *Tithonia diversifolia*; PP = *Pueraria phaseoloides*; CO = *Chromolaena odorata*; PM = *Panicum maximum*; AA = *Aspilia Africana*

Discussion

Relative to the control treatment, the significant increases in pH of soil in the plots of cassava – weed association, after cropping, corroborate the findings of Arena (2012); Ase (2014) and Cantillo (2014), who noted significant increases in pH of an Alfisol under *Tithonia diversifolia*, *Pueraria phaseoloides* in *Chromolaena odorata*, *Panicum maximum* and *Aspilia Africana* in cassava field after cropping. The significant increases in pH of Alfisol under these weed species can be ascribed to the significant increases in exchangeable basic cations (Ca, Mg, K and Na) on the exchange sites of Alfisol.

The significant increases in soil organic carbon (SOC), adduced to the weed species, agree with the observations of Vito (2012); Ase (2014) and Carasel (2014), who reported significant increases in SOC beneath *Tithonia diversifolia*, *Pueraria phaseoloides*, *Chromolaena odorata*, *Panicum maximum* and *Aspilia Africana* in cassava field after cropping. These observations can be explained in the light of litter or residues, produced by the weed species, which on decomposition, may have resulted in the return of a large amount of organic matter to the soil. The significant increases in SOC, associated with these weed species, point to the potentiality of weeds, like any other plants, as a source of organic matter, which is an important aspect of soil quality. The increase in soil organic matter (SOM), due to plant residues addition, has been widely researched. According to Nottidge *et al*. (2010), plant residues have a high potential of increasing SOM and maintaining soil fertility. Similarly, Singh (2008), noted that, the amount of plant nutrients, contained in plant residues is 60 times as high as the nutrients supplied to the soil through application of synthetic fertilizers.

The lowest SOC value, adduced to the weed – free treatment can be attributed to higher rate of oxidation of SOM in the weed - free plots. This is because, the tillage that attended hoe – weeding operation in the weed – free plots may have caused exposure of previously inaccessible and preserved SOM to action of the soil microbial biomass (Beare *et al*., 1992; Angers *et al*., 1993). So, the higher rate of oxidation of SOM in the weed free - plots can be implicated for the lowest SOC value, adduced to the weed - free treatment. This is because part of the organic carbon content of the organic matter may have been oxidized or converted into CO_2 gas, and consequently, organic carbon is lost in the form of carbon dioxide – C emission from the soil system.

The lowest SOC value for *Panicum maximum*, of all the weed species, can be attributed to the relatively low rate of decomposition of residues of *Panicum maximum* due to the highest lignin content of *Panicum maximum* residues, as attested to by the highest value of C/N ratio (Table 2).

The highest total N value for *Pueraria phaseoloides* is a further confirmation of ability of legumes to biologically fix atmospheric nitrogen into the soil, with resultant improved soil N status.

The lowest available P value of soil in the weed – free plots can be attributed to the lowest pH value of soil in the weed - free plots. This is because, the availability of P in the soil, depends on the pH of the soil medium, with available P decreasing with decreasing pH (Zorok, 2012). The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions, as a result of fixation by micro – nutrients, such as Fe and Al, which abound in acid soils (Zorok, 2012; Zynth, 2012).

The significantly higher values of N, P, K, Ca, Mg and Na, observed in the plots of cassava – weeds, compared to what obtained in the weed – free plots, after cropping, can be attributed to the significantly higher SOC values, recorded in the plots of cassava – weeds. This is because SOM has been reported as a reservoir of other plant nutrients, that is, other plant nutrients are integrally tied to it, and hence, the maintenance of SOM is paramount in sustaining other soil quality factors (Robertson *et al.* 1994; Arena, 2012; Ase, 2014).

The higher values of plant nutrients, recorded in all cassava – weed plots at the end of 2012 cropping season, compared to what obtained at the end of 2011 cropping season, can be ascribed to the residual effects of residues of weeds at the end of 2011 cropping season, coupled with additional weed residues during 2012 cropping season.

In view of the observed increases in plant nutrients, after cropping, associated with the weed species, it implies that, vegetation (weeds) can be instrumental in ameliorating a once badly degraded soil.

The significantly higher cassava root yield and yield components for the weed – free treatments, compared to its cassava – weeds counterparts, can be adduced to inter - specific competition among cassava and the weed species in cassava – weed associations, for growth factors, such as air, water, nutrients and light. The lowest cassava root yield and yield components for *Tithonia diversifolia*, corroborate the findings of Atilola (2012); Cantillo (2014), who observed lowest cassava root yield and yield components in the plots of *Tithonia diversifolia.* These findings imply that, of all the weed species, *Tithonia diversifolia* exerted the greatest detrimental effects on cassava. The greatest detrimental effects of *Tithonia diversifolia* on cassava, can be adduced to special attributes of *Tithonia diversifolia* , such as rapid growth habit, high population density, and large leaf area, all which enable it to develop canopy quickly, and hence, shades out any associated crop(s) and other weed(s) (Alalade, 2010; Aka, 2012; Olonitola, 2014). So the solar radiation denial of cassava due to the shading effects of *Tithonia diversifolia,* may have impaired photosynthetic activities in cassava, with resultant low cassava root yield.

Much as the lowest cassava root yield and yield components for *Tithonia diversifolia,* can be adduced to impaired photosynthetic activities in cassava, occasioned by solar radiation denial due to shading effects of *Tithonia diversifolia*, however, another factor that can be implicated for the observed lowest cassava root yield and yield components for *Tithonia diversifolia* is the loss of some cassava stands in the plots of cassava – *Tithonia diversifolia*. This is because, the solar radiation denial of cassava by *Tithonia diversifolia* , consequently resulted in etiolation of cassava, which in turn, predisposed cassava to lodging, with resultant loss of some cassava stands.

Of all the cassava – weed associations, cassava – *Pueraria phaseoloides* gave the highest cassava root yield and yield components, suggesting cassava's highest degree of tolerance of *Pueraria phaseoloides* of all the weed species. This implies that, the presence of *Pueraria phaseoloides* resulted in the least interference effects on cassava, compared to other weed species. In fact, the presence of *Pueraria phaseoloides* may have been beneficial to cassava, especially *Pueraria phaseolodes*, being a legume, may have improved the soil N status through biological fixation of atmospheric nitrogen into the soil system. Asides, *Pueraria phaseoloides*, being a cover plant, may have enhanced moisture conservation in the soil for the use of cassava during the periods of dry spells.

Although, weeds are known to reduce crop yields, through competition and /or interference, however, based on the results of the present study, it is apparent that, the extent of crop yield reduction, associated with weed competition and /or interference, depends on the kinds of weeds involved.

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