Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.6, No.2, 2016

Cassava-Groundnut Intercropping Under Mineral Fertilizer and Vermicomposts: Effect On Below Ground Microclimate, Nitrogen Mineralization and Cassava Foliage

Oroka, Frank Oke
Department of Agronomy, Delta State University, Asaba Campus, Nigeria

ABSTRACT
The study which was aimed at evaluating the relative effects of nutrient sources, cropping density and intercropping on selected soil variables and cassava crop foliage attributes was conducted at Teaching and Research Farm of the Delta State University, Abraka (latitude 5^0 46' and longitude 6^0 5') July 2008 to June 2009, in the humid rainforest zone of Southern Nigeria. The experimental design was a 4x3x3 factorial experiment in RCBD pattern using three replicates, consisting of four nutrient levels, three cropping densities and three cropping patterns. The 4 nutrient levels were zero application, 200kg NPKMg 12:12:17:2, 40 tons of water hyacinth/poultry manure-based vermicompost (VPM) and 40 tons of water hyacinth/cow dung-based vermicompost (VCD). The 3 cropping densities were 50,000, 100,000, and 200,000 plants ha^{-1}, while the three cropping patterns were sole groundnut, sole cassava and cassava-groundnut intercrop. Results showed that below ground temperature was not significantly affected by nutrient application, plant population and cropping systems. Vermicompost application significantly increased soil moisture and total soil nitrogen mineralized. Rate of leaf formation, leaf area index and stay green core of cassava were significantly increased by vermicompost application. Positive correlation was observed between soil N mineralized and soil moisture, rate of leaf formation and LAI.
Keywords: cassava, leaf area index, stay green score, soil mineralization, moisture, temperature

INTRODUCTION

The sensitive nature of field crops makes it impossible for them to take refuge from adverse conditions. Different environmental variables have resulted in a network of acclimatory mechanisms by field crops that promote optimal use of resources. Fluctuations in agro-environmental factors are usually dramatic ranging from a few seconds to minute or even days. As noted by Foyer and Paul (2001), nutrient and water supply can change within hours and days, while temperature can change within minutes.

Living organisms in both natural and human disturbed ecosystems such as farmlands depends on several of these environmental factors or variables to be functional. These factors may be biotic or abiotic and are present within the crop ecosystem. However the vegetative growth and yield of the crop has been found to be more influenced by the abiotic factors (Kazim 2003). Several researchers have indicated that the combination of biotic and abiotic factors determines the emergence, growth and yield of crops (Kerang, 2002; Odjugo, 2008; Gelon et al., 2003). Emetitiri, (2004) and Gelon (2003) observed that climatic and edaphic factors greatly influence crop performance in any given agroecosystem.

Sustainable agricultural practices are known to influence soil physical properties to maintain functional capacity of the soil for crop growth. Cassava is known to be a hardy crop because of its tolerance to poor soil and harsh climatic conditions. Hence it is extensively cultivated by small holder farmers from varied agricultural food systems. In the tropics, cassava is the fourth most important source of calorie in human diet, while in the world it ranks the sixth most important (Alves, 2002). Its ability to produce reasonable yields on degraded and low fertile soils where other crops cannot produce any yield makes it the valued crop of marginal farmers (Howeler, 2002).

The growth cycle of cassava consist of two major alternating periods; the vegetative growth and carbohydrate storage in the roots (Alves, 2002). The main organ of photosynthetic production in cassava is the foliage. Early vegetative phase, flowering pattern and storage of assimilate in the vegetative parts are greatly affected by leaf loss (Pandey, 1983). In Nigeria agro-environment, the crops cycle goes through the rainy season and dry season with varied temperature and soil moisture. Temperature and soil moisture are very important factors which influence the development and expansion of the leaves. Earlier reports have indicated the significance of environmental factors in leaf production and expansion, and the contribution of foliage to biomass production and crop yield (Foyer and Paul, 2001; Alves, 2002). Rabiu and Hong (2002) noted that soil temperature is a predictor variable which determines cassava storage root yield.

In other to achieve maximum crop productivity there must be equilibrium between the sink capacity (photosynthetic assimilate of active leaves) and the source activity (storage roots) during the growth cycle of cassava (Alves, 2002; Thandar, 2011). Since the sink capacity usually determine the source activity, farming systems that will sustain the productivity of the sink capacity, which is the crop foliage, becomes very significant.

Leaf formation and leaf size are affected by temperature, and consequently the general plant growth. Rate of leaf production is delayed at low temperatures (16^0C), and leaf area development decreases with reduced temperatures (Cock and Rosas, 1975). This is because the maximum size of each leaf is smaller and fewer leaves are produced at each apical region, although longevity of leaf is increased (Irikura et al. 1979). Leaves may remain on the plant for up to 200 days, at temperature within 15-24^0C (Irikura et al. 1979), and about 120 days for higher temperatures (Splittstoesser and Tunya, 1992), indicating faster shedding of leaves.

Sensitivity to soil water status has been observed to be one of the principal mechanisms that control tolerance to drought in cassava (Nuwanmaya et al. 2014). Cassava has adaptive capacity for soil water shortage through various foliage related mechanisms such as closing of stomata, leaf shedding, osmotic adjustment, reduced leaf area and ability to retain photosynthetic activity (El-Sharkawy, 1993; Nuwanmaya et al. 2014). The cassava plant has greater water use efficiency and water shortage tolerance ability when compared with other crops (El-Sharkawy and Cock, 1986). This response is due to its capacity to control stomata closure which reduces the rate of photosynthesis and reduction in transpiration losses. Under prolonged water shortage, cassava can reduce leave canopy by reducing the total leaf area (El-Sharkawy, 2007). Decline in shoot growth by 37%, and other shoot components such as plant height, leaf size and stem girth, due to moisture stress has been reported (Okogbeni et al. 2003; Aina et al., 2007). Alves and Setter (2004) also observed reduced leaf canopy and size and leaf fall as water conservation mechanisms in cassava. The rate of leaf formation per apex, apex number per unit area and leaf size and longevity has been shown to determine leaf area index (Lebot, 2009). High positive correlations have been shown to exist between leaf longevity, root yield and LAI, and rate of leaf formation in cassava (Lahai et al., 1999).

This study was therefore aimed at evaluating the variation in on-farm soil microclimate, nitrogen mineralization and foliage attributes of cassava as the influenced of intercropping, vermicomposts and chemical fertilizer.

MATERIALS AND METHODS

The study was carried out at experimental field of Teaching and Research Farm of the Delta State University, Abraka (latitude 5^0 46' and longitude 6^0 5') July 2008 to June 2009, in the humid rainforest zone of Southern Nigeria. The vermicomposting process has been described in earlier reports (Oroka, 2012). The experimental design was a 4x3x3 factorial experiment with a randomized complete design in three replicates, consisting of four nutrient levels, three cropping densities and three cropping patterns. The 4 nutrient levels were zero application, 200kg NPKMg 12:12:17:2, 40 tons of water hyacinth/poultry manure-based vermicompost (VPM) and 40 tons of water hyacinth/cow dung-based vermicompost (VCD). The proportion of dry water hyacinth to dry cow dung in the vermicompost was 75% to 25% respectively. The 3 cropping densities were 50,000, 100,000, and 200,000 plants ha^{-1}, while the three cropping patterns were sole groundnut, sole cassava and cassava-groundnut intercrop. Intercrop ratio of cassava (*Manihot esculenta* Crantz) and groundnut (*Arachis hypogea* L.) was 1:2 for all densities. Improved cassava (TMS 30572) and groundnut (Spanish 205) varieties were used for the study and planted on 6 x $4.5m^2$ plots.

Soil temperatures were monitored throughout the growing season of the crops using thermometers. Thermometers were placed at 20cm below the soil level. Daily readings were taken and presented as bimonthly averages. In situ net mineralization of soil nitrogen was determined with the soil core technique using methods earlier described by Gil and Fick (2001) within an incubation period of 60 days. The concentrations of nitrate –N and ammonium-N determined colorimetrically were per incubation period. Soil water content (moisture) at the beginning and end of the incubation period was determined using the gravimetric method on a subsample oven dried at 100^oC until constant weight.

Other foliage attribute such as leaf number of cassava and groundnut has been reported earlier (Oroka, 2012). Hence this report is only limited to selected crop foliage attributes in cassava such as rate of leaf formation, leaf area index (LAI) and stay green score (SGS). Rate of leaf formation was expressed as change in number of leaves in between measurements. Leaf area was estimated using the formula [$Y=5.81(L \times W)^{0.86}$], where *Y, L* and *W* are leaf area, maximum length and width of lobe respectively, Sutoro and Wargiono (1988). LAI was calculated as leaf area (m^2)/ground area (m^2). Stay green score (SGS) was visually rated on a scale of 1 to 9; where: 1 = a normal plant with a full canopy, most of formed leaves are retained and green, turgescent and photosynthetically active; 3 = 30% of the leaves have dropped, young leaves partially green, while less than 50% of older leaves are droopy and partially dry and wilted; 5 = 50% reduction in leaf number; most of the older leaves are droopy, wilted and dry (brown); 7 = 80% reduction of the leaf number as compared to full canopy; more than 75% of the remaining are wilted or brown; young leaves yellow/brown; 9 = complete defoliation of the stems, with a candlestick appearance and some dieback of the stems (Ekanayake, 1996). SGS is usually a combined effect of leaf ageing, drought or excess moisture condition, low night temperatures and harmattan winds (Ekanayake, 1996; Lenis et al., 2005; Lahai et al. 2013).

Data were subjected to an analysis of variance (ANOVA). Comparison of means was done by the least significant difference (LSD) at 5% level of probability. Correlation analysis of agro-environment variables and cassava foliage attributes was done using SPSS V. 16.

RESULTS AND DISCUSSION

Table 1: Effect of nutrient sources and plant population on below ground temperature (0^0C) in cassava-groundnut intercropping

Treatments	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun
Nutrients						
0kg	24.5	24.4	23.9	26.7	26.2	25.4
NPK (200kg/ha)	23.9	23.8	23.6	26.2	25.8	25.2
VP (400kg/ha)	22.0	22.0	21.6	25.4	24.8	24.3
VC (400kg/ha)	21.7	21.7	21.0	25.4	24.6	24.1
LSD (5%)	ns	ns	ns	ns	ns	ns
Density (plants /ha)						
50000	23.6	23.4	22.7	26.1	25.6	24.9
100000	23.0	23.0	22.6	25.9	25.3	24.9
200000	22.5	22.5	22.1	25.7	25.1	24.5
LSD (5%)	ns	ns	ns	ns	ns	ns
Cropping system						
Sole groundnut	23.1	22.9	-	-	-	-
Sole cassava	23.6	23.4	23.0	26.1	25.4	24.8
Cassava+ groundnut	22.4	22.1	22.1	25.7	25.3	24.7
LSD (5%)	ns	ns	ns	ns	ns	ns
Interactions						
Nutrient x density	1.32ns	6.75*	2.13ns	0.19ns	2.82ns	5.42*
Nutrient x cropping system	2.11ns	3.11ns	5.88*	1.41ns	3.70ns	8.02*
Density x cropping system	3.34ns	2.80ns	1.08ns	5.23*	3.11ns	5.28*
Nutrient x density cropping system	5.01*	7.22*	6.53*	4.11*	3.44ns	6.05*

*, ** Significant at 5% and 1% respectively.
Means with the same letters within the column are not significantly different ($P < 0.05$)

Below ground temperature at 20cm was not significantly affected by nutrient application, plant population and cropping systems (Table 1) throughout the growing season. Soil temperatures were lower in treatments with vermicompost application relative to the control. Cow dung-based vermicompost maintained relatively lower temperature compared to the poultry manure- based vermicompost. High plant populations also reduced soil temperature which may be due to closer crop canopy. Lower soil temperatures were more pronounced in intercrops compared to sole crops of either groundnut or cassava. Earlier studies (Wolfswinkel, 2003), showed that when intercrop and high plant density provides soil cover, a relative low temperature will be maintained within the crop canopy, providing a favourable microclimate for the associated crops. This was further buttressed in earlier reports by Russell (1973) who noted that vegetation intercepts a part or all of the incoming solar radiation and of the back radiation from the soil, thus helping to maintain lower soil temperature. Temperature was negatively correlated with all the parameters studied, except stay green score (SGS) (Table 7). The positive correlation of SGS with temperature definitely has a negative impact on photosynthetic capacity and productivity of the crop especially in warm climates.

Table 2: Effect of nutrient sources and plant population on soil moisture (mg kg^{-1} soil) in cassava-groundnut intercropping

Treatments	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun
Nutrients						
0kg	0.258c	0.277c	0.152b	0.093b	0.155c	0.202b
NPK (200kg/ha)	0.298b	0.329b	0.160b	0.093b	0.165c	0.214b
VP (400kg/ha)	0.337a	0.348ab	0.180a	0.108a	0.189b	0.241a
VC (400kg/ha)	0.342a	0.357a	0.187a	0.110a	0.210a	0.236a
LSD (5%)	0.035	0.028	0.015	0.009	0.012	0.018
Density (plants /ha)						
50000	0.303	0.321	0.166	0.104	0.187	0.236
100000	0.328	0.345	0.169	0.101	0.182	0.219
200000	0.293	0.316	0.169	0.097	0.170	0.211
LSD (5%)	ns	ns	ns	ns	ns	ns
Cropping system						
Sole groundnut	0.316	0.343	-	-	-	-
Sole cassava	0.302	0.321	0.170	0.099	0.178	0.221
Cassava+ groundnut	0.306	0.319	0.170	0.103	0.182	0.223
LSD (5%)	ns	ns	ns	ns	ns	ns
Interactions						
Nutrient x density	4.65*	3.01ns	2.78ns	5.01*	5.22*	6.01*
Nutrient x cropping system	2.11ns	3.25ns	1.91ns	2.81ns	4.89*	3.01ns
Density x cropping system	1.97ns	0.91ns	1.75ns	2.34ns	1.7ns	2.8ns
Nutrient x density x cropping system	4.92*	5.09*	4.83*	6.91*	3.16ns	4.71*

*, ** Significant at 5% and 1% respectively.

Means with the same letters within the column are not significantly different (P <0.05)

Soil moisture was significantly (*P*<0.05) influenced by nutrient sources. The application of vermicomposts, significantly increased soil moisture when compared to the control by 33%, 29%, 23%, 18%, 36% and 17% in July/August, September/October, November/December, January/February, March/April and May/June respectively. The vermicompost which is naked organic matter increased soil moisture conservation either by reducing the rain drops impact on the soil, enhancing water percolation or reducing velocity of surface water flow. Plant population and cropping system indicated no significant effect on soil moisture. Soil moisture was more conserved with high plant population (100000 plants/ha), however at 200000 plants/ha, moisture content was reduced. Soil moisture was lower in intercrop relative to sole the crop within the first four MAP, when groundnut was still in the field. However, after harvest of groundnut, the intercrop maintained higher soil moisture relative to sole cassava. Lowest soil moisture was observed between the months of November 2008 to April 2009.

Table 3: Effect of nutrient sources and plant population on total soil nitrogen (NH_4 +NO_3^-_) mineralization (mg kg^{-1} soil) in cassava-groundnut intercropping

Treatments	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun
Nutrients						
0kg	14.9c	16.6c	13.7c	9.9b	11.3c	11.2b
NPK (200kg/ha)	27.6b	29.8b	20.6b	12.6b	14.6b	16.2b
VP (400kg/ha)	45.6a	47.1a	42.5a	32.0a	29.2a	29.3a
VC (400kg/ha)	41.9a	43.1a	45.8a	33.6a	32.4a	32.0a
LSD (5%)	10.8	8.63	3.5	3.37	2.8	5.8
Density (plants /ha)						
50000	30.1	31.0	27.9b	20.9	20.8	20.9
100000	33.3	35.0	31.9a	22.3	22.2	22.5
200000	34.2	36.4	32.1a	23.0	22.6	23.8
LSD (5%)	ns	ns	3.3	ns	ns	ns
Cropping system						
Sole groundnut	32.0	33.7				
Sole cassava	30.4	32.2	27.8b	20.3b	20.0	20.7
Cassava+ groundnut	35.1	36.5	33.5a	23.8a	23.7	24.0
LSD (5%)	ns	ns	3.9	2.7	ns	ns
Interactions						
Nutrient x density	6.32*	7.63*	31.40**	12.94*	8.20*	6.99*
Nutrient x cropping system	1.53ns	4.51*	30.31**	8.41*	1.98ns	2.04ns
Density x cropping system	39.03**	12.19**	42.51**	203.15**	28.62**	11.52*
Nutrient x density x cropping system	0.05ns	101.18**	170.35**	1.62ns	1.09ns	28.33**

*, ** Significant at 5% and 1% respectively.
Means with the same letters within the column are not significantly different (P <0.05)

Soil organic amendment in form of vermicompost resulted in significant (*P*<0.05) increase in total soil N mineralized. Mineralized N was slightly higher in the poultry manure-based vermicompost (VP) within the first 4 MAP compared to the VC, subsequently the cow dung based vermicompost (VC) maintained a higher mineralized N. On the average the least mineralized soil N was obtained in the January/February. Plant population showed a significant influence on total soil nitrogen mineralized in November /December The significant effect of cropping system was observed between the months of November and February. These periods also coincided with period of lower rate of leaf formation and higher stay green score. Total soil mineralized N was slightly more pronounce with highest plant populations (200000 plants/ha) and in soils with intercrop. Intercrop and high plant population has been show to maintain dense crop canopy which prevents loss of nutrients due to burning of organic matter in the soil (Wolfswinkel, 2003). Positive correlation was observed between soil N mineralized and soil moisture, rate of leaf formation and LAI. The increased soil N mineralized with soil moisture may be attributed to increased soil microbial respiration. The results are confirmed by earlier studies (Zhou et al., 2014; Deressa, 2015) which indicated that at increased soil moisture, soil microbial (or heterotrophic) respiration rates also increased, which consequently increased mineralized N.

Table 4: Effect of nutrient sources and plant population on rate of leaf formation (day^{-1} $plant^{-1}$) of cassava in cassava-groundnut intercropping

	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun
Treatments						
Nutrients						
0kg	1.2	1.3b	1.1d	0.9b	1.1c	1.1c
NPK (200kg/ha)	1.3	1.4b	1.3c	1.3a	1.3b	1.3b
VP (400kg/ha)	1.4	1.7a	1.4b	1.4a	1.5a	1.5a
VC (400kg/ha)	1.3	1.6a	1.5a	1.4a	1.5a	1.5a
LSD (5%)	ns	0.2	0.1	0.2	0.1	0.1
Density (plants /ha)						
50000	1.3	1.6	1.3	1.2	1.3	1.3
100000	1.4	1.5	1.5	1.3	1.4	1.4
200000	1.3	1.4	1.3	1.2	1.3	1.3
LSD (5%)	ns	ns	ns	ns	ns	ns
Cropping system						
Sole cassava	1.3	1.6	1.4	1.3	1.4	1.4
Cassava+ groundnut	1.3	1.4	1.3	1.2	1.3	1.3
LSD (5%)	ns	ns	ns	ns	ns	ns
Interactions						
Nutrient x density	0.14ns	4.67*	5.01*	2.01ns	0.44ns	0.44ns
Nutrient x cropping system	2.83ns	6.11*	7.11*	6.27**	5.11*	5.11*
Density x cropping system	1.98ns	2.7ns	3.01ns	4.11*	0.21ns	0.21ns
Nutrient x density x cropping system	0.77ns	9.01*	12.01**	10.13**	9.84**	9.84**

*, ** Significant at 5% and 1% respectively.
Means with the same letters within the column are not significantly different (P <0.05)

Rate of leaf formation was more pronounced in soils with vermicompost organic amendments relative to mineral fertilizer and control treatments. Relative to the control, cassava leaves were formed at a faster rate in the vermicomposts (VP and VC) during the growing season. Higher rate of leaf formation in the vermicompost was more evident in September/October with increase of 23.5% and 18.8% in VP (water hyacinth +poultry manure vermicompost) and VC (water hyacinth +cow dung vermicompost) respectively. Increased rate of leaf formation in vermicomposts confirms the report of other researchers (Akanbi et al., 2000; Ghosh et al., 2006) that nutrient availability is a major determinant of plant photosynthetic capacity. Although no observed significant effect of plant population, rate at which new leaves were formed only decreased when plant population was above 100000 plants /ha. Monocropped cassava had better rate of leaf formation than those intercropped with groundnut, although cropping system did not show any significant effect.

Table 5: Effect of nutrient sources and plant population on leaf area index (LAI) of cassava in cassava-groundnut intercropping

	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun
Treatments						
Nutrients						
0kg	1.0c	1.2c	0.9b	0.8c	0.9b	0.9b
NPK (200kg/ha)	1.6b	1.7b	1.6a	1.5b	1.6a	1.6a
VP (400kg/ha)	1.9a	2.0a	1.8a	1.6ab	1.7a	1.8a
VC (400kg/ha)	1.8a	1.9ab	1.8a	1.7a	1.8a	1.8a
LSD (5%)	0.2	0.3	0.3	0.2	0.4	0.4
Density (plants /ha)						
50000	1.4	1.6	1.4c	1.3b	1.4c	1.4c
100000	1.7	1.8	1.6ac	1.5a	1.6a	1.7a
200000	1.7	1.7	1.5b	1.3b	1.5b	1.5b
LSD (5%)	0.1	ns	0.1	0.2	0.1	0.1
Cropping system						
Sole cassava	1.6	1.7	1.5	1.5	1.4	1.5
Cassava+ groundnut	1.5	1.7	1.5	1.4	1.5	1.6
LSD (5%)	ns	ns	ns	ns	ns	ns
Interactions						
Nutrient x density	5.07*	4.08*	5.11*	7.51**	2.13ns	2.13ns
Nutrient x cropping system	6.11*	2.84ns	11.05**	3.18ns	1.09ns	1.09ns
Density x cropping system	2.15ns	5.17*	3.04ns	2.19ns	6.11*	6.11*
Nutrient x density x cropping system	1.59ns	2.14ns	6.15*	5.91*	5.01*	5.01*

*, ** Significant at 5% and 1% respectively.
Means with the same letters within the column are not significantly different (P <0.05)

Organic nutrient applications showed significant effect on leaf area index (LAI) of cassava (Table 5). In the water hyacinth+ poultry manure vermicompost (VP), LAI increased over the control by 90% (Jul/Aug), 67% (Sep/Oct), 100% (Nov/Dec), 100% (Jan/Feb), 47% (Mar/Apr) and 100% (May/Jun), while in water hyacinth+ cow dung vermicompost (VC), LAI increase was observed to be 80%, 58%, 100%, 47%, 100% and 100% at same time. Planting density and cropping system did not have any significant effect. Wider spacing with plant population at 50000 plants /ha showed lowest LAI during crop growth season. The reduced LAI in high plant densities may be due to increased competition. This confirms the observations of Fereira et al. (2008) and Rizzardi (2001) that under competition plant tends to have reduced leaf dimensions resulting in slower development of leaf area. However no consistent trend was observed with cropping system. LAI positively correlated with soil moisture, soil nitrogen mineralization and rate of leaf formation, indicating that an increase in these parameters will result in increased LAI. The positive correlation of LAI with moisture is expected since progressive increase in hydro-stress has been shown to induce dechlorophyllated and yellowed leaves in cassava (Nuwanmaya, et al. 2014) which further promotes leaf size reduction and defoliation. However the converse was the case with soil temperature and SGS which were negatively correlated with LAI (Table 7).

Table 6: Effect of nutrient sources and plant population on stay green score (SGS) of cassava in cassava-groundnut intercropping

	Jul/Aug	Sep/Oct	Nov/Dec	Jan/Feb	Mar/Apr	May/Jun
Treatments						
Nutrients						
0kg	3.2a	3.6a	3.9a	4.1a	3.6a	3.5a
NPK (200kg/ha)	3.0bc	3.1b	3.6b	3.9a	3.5a	3.2b
VP (400kg/ha)	2.7d	2.7c	3.0c	3.1b	3.0b	3.0c
VC (400kg/ha)	2.9c	2.9bc	2.7d	2.9b	2.9b	2.7d
LSD (5%)	0.2	0.4	0.3	0.5	0.3	0.2
Density (plants /ha)						
50000	2.9	3.0	3.0	3.4	3.2	3.1
100000	2.9	3.0	3.2	3.5	3.3	3.1
200000	3.1	3.1	3.5	3.7	3.4	3.4
LSD (5%)	ns	ns	ns	ns	ns	ns
Cropping system						
Sole cassava	2.9	3.0	3.2	3.5	3.2	3.1
Cassava+ groundnut	3.0	3.1	3.2	3.6	3.3	3.2
LSD (5%)	ns	ns	ns	ns	ns	ns
Interactions						
Nutrient x density	6.11*	12.01**	7.54*	6.23*	5.75*	11.58*
Nutrient x cropping system	3.07ns	5.22*	5.00*	2.81ns	3.04ns	2.90ns
Density x cropping system	2.01ns	1.89ns	2.75ns	3.01ns	1.08ns	5.15*
Nutrient x density x cropping system	5.11*	6.01*	9.12*	3.21ns	6.89*	7.12*

*, ** Significant at 5% and 1% respectively.
Means with the same letters within the column are not significantly different (P <0.05)

One of the main strategies of maintaining high cassava root yield under abiotic stress is sustaining photosynthetically active leaf area duration throughout the crop growing season. Stay green score (SGS) is the indirect way of measuring LAD (Ekanayake et al., 1996; Lenis et al., 2005). Except nutrient treatments, cropping density and cropping system showed no significant effect on stay green score or leaf area duration (LAD) of cassava foliage (Table 6). SGS was lower in vermicompost treatments compared to the control and mineral fertilizer. Lower crop densities and sole cassava maintained lower SGS during the crop growing season. With reduced SGS, there is a corresponding increase in LAD, which indicates that organic nutrient applications in form of vermicomposts, lower plant population and sole cassava cropping gave higher LAD. SGS correlated negatively with soil moisture, soil mineralized nitrogen, rate of leaf formation and leaf area index, indicating that these soil and cassava foliage attributes increases with LAD, while higher soil temperatures reduces LAD (Table 7). This agrees with the observations of previous studies (El-Sharkawy et al. 1990; Osiru et al. 1995) that farming practices that positively enhance leaf longevity also influence leaf net photosynthetic activity and performance in cassava.

Table 7: Correlation analysis of microclimatic factors and crop foliage attributes

	Temp	SOM	SMN	RLF	LAI	SGS
Temp	-					
SOM	-0.790**	-				
SMN	-0.950**	0.902**	-			
RLF	-0.604**	0.833**	0.748**	-		
LAI	-0.785**	0.835**	0.838**	0.831**	-	
SGS	0.705**	-0.900**	-0.824**	-0.750**	-0.773**	-

** Significant at $P < 0.01$
Temp= temperature; SOM: soil moisture; RLF: rate of leaf formation; LAI: leaf area index; SMN: soil mineralization; SGS:

stay green score

The results obtained from the study has shown that farming practices which increase soil organic matter such as application of vermicompost can have positive effects on soil microclimate and enhance foliage attributes which further promote the photosynthetic capacity of the crop.

ACKNOWLEDGEMENT

This research was conducted through a research grant to the author by the International Foundation for Science (IFS), Stockholm, Sweden

REFERENCES

Aina, O.O, Dixon, A.G.O and Akinrinde, E.A. (2007) Effect of soil moisture stress on growth and yield of cassava in Nigeria Pakistan Journal of Biological Sciences. 10(18):3085-3090

Akanbi, W.B; Bayeiwu, R.A and Tairu, F.M. (2000) Effect of maize-stover compost on growth and yield of celosia (C*elosia argentea* L.) *Journal of Agriculture Forestry and Fisheries.* 1:7-10

Alves, A.A.C. (2002) Cassava botany and physiology In Hillocks, R.J, Thresh, J.M. and Bellotti, A.C. (Ed.). *Cassava: Biology, Production and Utilization.* CABI, Wallingford, UK.

Alves, A.C. and Setter, T.L. (2004) Abscisic acid accumulation and osmotic adjustment in cassava under water deficit Envtal Exp. Bot. 51(3):259-271

Cock, J.H. and Rosas, S. (1975) Ecophysiology of cassava. In (eds) Symposium on Ecophysiology of Tropical Crops. Communications Division, CEPLAC, Bahla, Brazil, 1-14

Deressa A. (2015) Effects of Soil Moisture and Temperature on Carbon and Nitrogen Mineralization in Grassland Soils Fertilized with Improved Cattle Slurry Manure with and without Manure Additive Journal of Environment and Human 2(1):1-9

El-Sharkawy, M.A. (1993) Drought tolerant cassava for Africa, Asia and Latin America. Breeding projects work to stabilize productivity without increasing pressures on limited natural resources Bio. Am. Inst. Bio. Sci. 43:441-561

El-Sharkawy, M.A. (2007). Physiological characteristics of cassava tolerance to prolonged drought in the tropics: Implications for breeding cultivars adapted to seasonally dry and semi-arid environments. *Braz. J. Plant Physiol.* 19: 83-98.

El-Sharkawy, M.A. and Cock, J.H. (1986). The humidity factor in stomatal control and its effects on crop productivity. In: Marcelle, R., Clijsters, H. and van Poucke, M. (Ed.). *Biological Control of Photosynthesis*. Martinus Nijhoff Publishers, Dordrecht, pp. 187-198

El-Sharkawy MA, Cock JH, Lynam JK, Hernandez AP, Cadavid LF (1990) Relationships between biomass, root yield and single-leaf photosynthesis in field-grown cassava. Field Crops Research 25: 183–201

Ekanayake, I.J. (1996) Cassava: Procedures for growth analysis IITA, Ibadan

Emetitiri, A.O. (2004). The effects of intercropping on the yield of yam and cassava in Delta State, Nigeria. J. Environ. Knowledge, 14(1): 64-80

Fereira, E.A. et al. (2008). Potencial competitivo de biótipos de azevém (*Lolium multiflorum*).*Planta Daninha*, Vol.26, No.2, (June 2008), pp.261-269

Foyer, C.H and Paul, M.J. Source-sink relationships. Encyclopedia of Life Sciences. Nature Publishing; 2001; 1-11.

Galon, L., Germani C.; Ferreira,A. Ignacio A. da Silva F, Clevison L. Giacobbo and André A.(2003)Influence of biotic and abiotic stress factors on physiological traits of sugarcane varieties http://dx.doi.org/10.5772/55255

Ghosh, P.K., Manna, M.C., Bandyoppahyay, K.K., Ajay,A.K., Tripathi,R.H., Wanjari, R.H., Hati, A.K., Misra, C.L., Acharya, C.L. and Subba Rao, A. Interspecific interaction and nutrient use in soybean/sorgum intercropping system Agron. J. 2006; 98:1097-1108

Howeler, R.H. (2002). Cassava mineral nutrition and fertilization. In: Hillocks, R.J, Thresh, J.M. and Bellotti, A.C. (Ed.). *Cassava: Biology, Production and Utilization.* CABI, Wallingford, UK

Irikura, Y., Cock, J.H. and Kawano, K. The physiological basis of genotype temperature interaction in cassava Field Crops Research 1979, 2:227-239

Kazem CJ (2003). Evaluation of microclimatic factors affecting root crops growth in the Middle Belt of Nigeria. J. Agric. Dev. 13(2): 8-15

Kerang, B.G. (2002). Assessing the micro- and macro-environmental factors determining the yield of cassava Northern Nigeria J. Environ. Knowledge, 12(2): 36-44

Lahai, M. T. Ekanayake, I. J. and Koroma, J. P. C. (2013) Influence of canopy structure on yield of cassava cultivars at various toposequences of an inland valley agro ecosystem Journal of Agricultural Biotechnology and Sustainable Development , 2013; 5(3):36-47

Lahai M.T., George, J.B., Ekanayake, I.J. (1999). Cassava (*Manihot esculenta* Crantz) growth indices, root yield and its components in upland and inland valley ecologies of Sierra Leone. J. Agro. Crop Sci. 182:239-247

Lebot V (2009). Tropical root and tyber crops: cassava, sweet potato, yam and aroids. CABI publication. Amazon.com. P. 413

Lenis J.I., Calie F, Jaramillo G, Perez J.C., Ceballos H, Cock J.H. (2005).Leaf retention and cassava productivity. Field Crops Res. 95:126-134

Nuwanmaya, E., Rubaihayo, P.R., Mukasa, S.;Kyamanwa, S., Hawumba J. F. and Baguma, Y. (2014) Biochemical and secondary metabolites changes under moisture and temperature stress in cassava (*Manihot esculentus* Crantz). African Journal of Biotechnology. 13(31):3173-3186

Odjugo Peter A. O. (2008) The impact of tillage systems on soil microclimate,growth and yield of cassava (*Manihot utilisima*) in Midwestern Nigeria African Journal of Agricultural Research 3 (3),: 225-233

Okogbenin, E., Ekanayake, I.J. and Porto, M.C.M. Genotypic variability in adaptation response in selected clones of cassava to drought stress in the sudan savanna zone of Nigeria J.Agron. Crop. Sci. 2003; 189:376-389

Osiru D.S.O., Hahn SK, Osonubi O (1995) Mechanisms of drought tolerance in cassava. Journal of African Crop Science 2: 233-246

Pandey, R.K. (1983) Influence of defoliation on seed yield in cowpea (*Vigna unguiculata* (L) Walp.) in a sub-Tropical environment. *Field Crops Research.* 1983; 7: 249 -256

Rabiu S.U and Hong A (2002). Effects of mulching on cassava growth and yield in Ondo State, Nigeria. J. Environ. Knowledge, 12(2): 105-119

Rizzardi, M.A. et al. (2001). Competição por recursos do solo entre ervas daninhas e culturas. *Ciencia Rural*, Vol.31, No.4, (December 2001), pp.707-714,

Russell, W.E. (1973) Soil conditions and plant growth 10th ed. Longman, London

Splittstoesser, W.E. and Tunya, G.O. (1992) Crop physiology of cassava. Horticultural Reviews, 1992, 13: 105-129

Sutoro and Wargiono, J. (1988) Method for estimating leaf area of cassava (*Manihot esculenta* Crantz) Seminar of Bogor Research Institute for Food Crops 1986 Bogor Indonesia; BPTP;6-13

Thandar N. (2011) Improving Agronomic Efficiency In Cassava- Based Farming Systems In The Democratic Republic Of Congo Using Organic And Inorganic Inputs Ph. D Theis Kenyatta University, Kenya

Wolfswinkel. (2003) Intercropping of annual food crops Agroref. No. 4 Agromisa Foundation, The Netherlands. 2003

Zhou W, Hui D, Shen W (2014) Effects of Soil Moisture on the Temperature Sensitivity of Soil Heterotrophic Respiration: A Laboratory Incubation Study. PLoS ONE 9(3):1-10