Universal Journal of Agricultural Research 7(5): 189-195, 2019 http://www.hrpub.org
DOI: 10.13189/ujar.2019.070503

Potential of Vermesfluid for Sustainable Cassava Production on a Degraded Ultisol of Southeastern Nigeria

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Received December 10, 2018; Revised January 30, 2019; Accepted July 16, 2019

Abstract Field experiments were conducted at the eastern research farm of the National Root Crops Research Institute (NRCRI), Umudike, southeastern Nigeria (SEN), in 2016 and 2017 cropping seasons, to evaluate the effects of inorganic (NPK) fertilizer and vermesfluid on the root yield of cassava (TME 419). The experiment was a single-factorial in a randomized complete block design (RCBD) with three replications. The treatments comprised 16 percentage combinations of the recommended rate of NPK fertilizer (600 kg/ha) and the maximum recommended vermesfluid concentration (4%). The vermesfluid was applied foliarly 4 times at a 4 weekly interval, while the NPK fertilizer was banded in at 6 weeks after planting. The cassava was harvested at 11 months after planting and the yield estimated in tonnes per hectare (t/ha). The results of a 2-year average showed that application of vermesfluid alone between the recommended concentration range of 3 and 4%, induced similar yield responses but resulted in a non-significant and significant reduction in cassava root yield below those of the control (T_0) and the application of the full dosage of NPK fertilizer (T_7), respectively. However, combined application of 75% of the recommended rate of NPK fertilizer with 100% of vermesfluid concentration (T_{12}), gave exceptionally high cassava yield of 57.8t/ha, which significantly out-yielded every other treatment including T_7 and T_0 by 18.6% and 55.2%, respectively. On the basis of this result, T_{12}, which not only gave the best yield but also reduced the application rate of the NPK fertilizer with the associated cost and environmental risk components by 25%, is recommended for sustainable cassava production on a degraded Ultisol of SEN.

Keywords Vermesfluid, Inorganic (NPK) Fertilizer, Foliar Application and Cassava Root Yield

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a root crop with diverse agro-industrial end uses and many value-added products. In Nigeria, as in most countries of its cultivation, cassava is a major staple food security crop with immense export-market, income-generating and poverty-alleviation (FMANR, 19997) potentials.

Although cassava is utilised domestically in most countries, but in Thailand, it is desired mainly for the export-market, while China is presently a major exporter. Potential markets for cassava are mainly in the area of starch and starch-based products, for domestic animal feed production and for processed food and recently, a rapidly developing new market for ethanol production in Thailand, China and the Philippines. To maintain cassava's competitiveness in the world markets, further research is required to increase yields, reduce production costs and increase nutritional value of roots among others.

Nigeria is the world's largest cassava producer with her annual production of over 45 million tonnes, contributing over 19% of the global cassava production (Wikipedia, 2017). The production of cassava could be increased through expansion in the area under its cultivation and increased productivity (i.e. increase in yield per unit area). However, Nigeria's cassava production figure comes more from the former than the later, which is reportedly very low (10.6t/ha) on farmers' field (IITA, 2013).

The growing Nigerian population has necessitated increased demand for food (Eneje and Ukut, 2012). The consequential decrease in arable land for cassava production has compelled increased intensity of land use with the resultant decline in soil fertility and the need for increased productivity to meet the growing demand for cassava for the domestic and export markets.

Fertilizer application has been reported to be an important option for farmers to adopt in order to improve crop yields in most soils of southeastern Nigeria under increased land use intensity (Ikeorgu, 1999). However, continuous and prolonged use of chemical fertilizer under intensive farming system and shortened fallow periods have been found to release nitrous oxide (N_2O) and Carbon dioxide (CO_2), the two most potent greenhouse gases that cause global warming and exacerbate the negative impact of climate change (Smith *et al*., 2007; Vasileva, 2007; Vasileva and Vasilev, 2017). Furthermore, prolonged inorganic fertilization also leads to nutrients depletion/ imbalance, increased soil acidity, soil erosion and land degradation, with attendant low crop yields (Tandon, 1993; Isola, 1998; Uyobisere and Elemo, 2000; Mullins, 2009). Increased acidity as a result of excessive inorganic fertilization also kills micro-organisms, which in turn makes the soil sterile and unproductive, besides being widely known to increase groundwater contamination with nitrates.

Vermesfluid, an end-product of vermis, is a high quality earthworm-mediated liquid organic regulator with growth stimulating and fertilizing effects. It is an environmental-friendly, economically advantageous and easily applicable product with optimal nutrition and better nutrient absorption, increased chlorophyll content and higher photosynthetic ability, and higher crop yields attainment effects.

Besides conferring more resistance against fungal diseases and pests on crops, it also improves ground and surface water quality and has less no toxic matters and residue of heavy metals. It also has the potential to increase micro flora activity and thus eliminate the sterility of the soil caused by reckless and excessive chemical fertilization.

Current practice on the use of vermesfluid has demonstrated the possibility of reducing chemical applications by 40%. And higher yield and quality (increased vitamin or antioxidant-content in fruits and higher sugar content) of some crops such as potato, tomato, maize, sugar beet etc. in temperate climates have been fully confirmed by users when vermesfluid is applied between the recommended concentration range of 3 and 4% (Cervena and Pecl, 2015). There is need to expand the frontier of vermesfluid application in terms of tropical climates and hardier longer-duration root crops. Therefore, the objective of this study is to evaluate the potential of vermesfluid, combined with or without mineral fertilizer, for sustainable cassava production on a degraded humid tropical Ultisol at Umudike, SEN.

2. Materials and Methods

2.1. Description of Site and Location of Experiment

The trial was conducted in 2016 and 2017 cropping seasons at the eastern research farm of the National Root Crops Research Institute (NRCRI), Umudike (Lat. 05^{o}29^I N and Long.07 32^I E; altitude 122m asl) in Abia State, Nigeria. The location is within the rainforest agro-ecological zone of southeastern Nigeria (SEN) and the climate is typically humid tropical characterized by a mean annual rainfall of between 2000mm and over 2571mm and temperature ranging from 25 to 33^{o}C with two distinct seasons, the wet season from April to October and the dry season from November to March. The basic (rainfall) meteorological data during the growing seasons (April 2016-March 2017 and April 2017-March 2018) in the 2 years of experimentation are as shown in Table 2.

2.2. Soil Analysis

The soil, which has been derived from coastal plain sediments, has been classified as Typic Paleudult (Soil Survey Staff, 1999). Composite auger soil samples were collected from the experimental sites at 0 – 20 cm soil depth in both years prior to sowing the cassava crop. The soil samples were air-dried, ground, well mixed and passed through a 2-mm sieve before being analysed for some physical and chemical properties using standard analytical methods as described by Udo and Ogunwale (1978). The soil data are as presented in Table 1.

2.3. Land Preparation

In each year, the experimental site, which had been under one and a half ($1\frac{1}{2}$) years of predominantly guinea grass (*Panicum maximum*), interspersed with giant grass (*Mimosa invsa*) fallow, was mechanically slashed, ploughed, harrowed and ridged with a tractor, manually de-trashed and demarcated into 3m x 3m experimental plots.

2.4. Treatments and Design

Treatments comprised 15 percentage combinations of the full recommended rate of inorganic fertilizer (600 kg/ha NPK 15:15:15) for cassava production on low N and K soil fertility class and 100% of the recommended maximum vermesfluid application concentration (i.e. 4%) for crop production as well as a control without additives. These formed a total of 16 treatment combinations which were laid out as a single factorial experiment in a randomised complete block design (RCBD) and replicated thrice.

2.5. Cultural Management Practices

Cassava stems of variety TME 419 were cut into 20-25cm planting (stake) lengths and planted at a spacing of 1m x 1m on the crest of the ridges in the experimental plots on 25th April and 20th April, 2016 and 2017, respectively, giving a population of 10, 000 plants per hectare. Pre-emergent herbicides (190 ml primextra plus 200 ml round up in a 15- litre capacity knapsack x 4) were applied at 2 days after planting in both years. Missing plots of non-sprouted/weakly sprouted cassava plantings were supplied at 3-4 weeks after planting (3-4 WAP) to ensure the plant population was maintained. The vermesfluid component of the treatments was foliar applied four times, in each year, at four weekly intervals beginning from 4 WAP, while the NPK fertilizer was applied at 6 WAP in both years. One additional manual weeding at 5 WAP and two (2) post-emergent herbicide applications were carried out during the crop's growth cycle to ease data collection and harvesting on 15th March, 2017 and 12th March, 2018, respectively (less than 11 months after planting in each year). The fresh root yield in tonnes per hectare (t/ha) was estimated from the experimental plot yield (kg/plot).

2.6. Statistical Data Analysis

The data obtained were subjected to analysis of Variance (ANOVA) using GENSTAT (2003) to assess significance of treatment effects. Means were compared using Fisher's Least Significant Difference (LSD) at 5% probability level.

3. Results and Discussion

3.1. Soil Properties

Some soil properties at the experimental sites before cropping in both years (2016 and 2017) (Table 1) showed the surface soils (0-20cm) were sandy loam in texture, underlining their suitability for ground-storage crop production due to the existence of adequate edaphic condition of good drainage and aeration as well as less likely risk of compaction and mechanical impedance for good rooting and tuberization of the cassava crop. However, the soils presented low water and nutrient retention capacity with high leaching potentials, due to their low effective cation exchange capacity (ECEC) and low organic matter (OM) contents, which may negatively affect crop growth. The soil pH varied from moderately (in 2016) to strongly (in 2017) acidic in reaction but with low exchange acidity (EA) and hence no danger to Aluminium (Al) toxicity and unlikeness to limit cassava production since the pH is above the critical level of 4.6 for cassava production. The total Nitrogen (N) and exchangeable Potassium (K) were low and also was exchangeable (Ca) content but available Phosphorus (Bray-2P) and exchangeable Magnesium (Mg) had levels considered moderate and moderate to high, respectively. These indicate the soils to be generally nutritionally deficient with expected responses to supplemental N, P and K fertilization in advisedly, split doses or at a time nutrient supply synchronises with proper root development for reduced leaching potential and enhanced nutrient use efficiency. Although the ECEC was low, the high level of the base saturation (BS) suggests that the exchange complex is dominated by basic cations, especially Ca^{2+} and Mg^{2+} and that the soils are not excessively leached and generally fertile (>50% BS) (Landon, 1984) and liming not advisable (pH>4.5).

3.2. Climatic (Rainfall) Condition

The basic monthly rainfall characteristics during the cassava growing seasons in the 2 years of experimentation are shown in Table 2. No substantial year to year variation in seasonal precipitation and number of rainy days were observed during the cassava crop growth periods. However, the 2016/2017 (25th April. 2016-15th March, 2017) growing season was slightly wetter (2,129.4mm) with lesser number of rainy days (110 days) than the 2017/18 (20th April, 2017-12th March, 2018) growing season with 2,042.4mm rainfall in 117 rainy days. These indicate that while rainfall amount was slightly higher in the 2016/17 cropping season, its distribution was slightly better (lesser amount but more frequent or shorter intervals of occurrence) in the subsequent 2017/2018 season. This is possibly because of the 2 months of drought (water stress) experienced in December 2017 and January 2018 within 2017/18 season, while there was only 1 month drought experienced in February 2016 of the 2016/17 growing season. The first quarter (January – March) of 2016 had 257.7mm rainfall in nine (9) rainfall events (number of rainy days), while that of 2017, for the corresponding period, was 131.5mm in seven (7) rainfall events (data not shown). However, before the establishment of the cassava crop in April of both years, the amount of rainfall and its events had improved to 366.9mmm in 15 rainfall events in 2016 and 265.9mm in 12 rainfall events in 2017. This indicates that though, generally there was no sufficient rainfall and its distribution for the preparatory phase of the farming season. In the 1st quarter of both years, the amount of rainfall and distribution were adequate to ensure little or no occurrence of water stress during the critical cassava establishment periods in both years. Adiele *et a*l. (2005) reported that rainfall amount of 208mm and distribution of 12 rainy days in the 1st quarter of the year was sufficient for the preparatory phase of the farming season. Furthermore, the data also revealed an earlier onset of rainy season, in March 2016, than the April in 2017 and ending in October in both years. This further indicates the onset of dry season, 7 and 8 months after cassava establishment for the 2016 and 2017 seasons, respectively, which implies that the cassava experienced water stress during planting affects cassava established, while that during root and tuber formation/bulking reduced cassava yield significantly and that water stress after 7 MAP had no influence on yield (Agbaje and Akinlosotu, 2004; El-Sharkawy *et al*., 1998). All these suggest that the cassava crop were exposed to favourable agro-climatic environmental condition in both years and that only unfavourable edaphic conditions and nutrient(s) deficiencies could limit crop yield performance.

3.3. Cassava Root Yield

The treatments (varying percentage) combinations of the recommended rate of NPK 15:15:15 fertilizer (F) and vermesfluid (V) concentration significantly (P<0.001) influenced cassava fresh root yield in both years (2016 and 2017 respectively), and also the combined yield (2-year average) (Table 3). The root yield in 2016, varied from a minimum of 29.73t/ha in T_{15} (% F: 75 %V) application of 75 % of vermesfluid concentration alone to a maximum of 54.51t/ha in T_{10} (75 % F: 50 % V i.e. application of 75% of NPK fertilizer rate in combination with 50 % vermesfluid concentration). The root yield in T_{15} was statistically at par (P>0.05) with those of T_5 (25 % F:75 % V) and T_8 (0 % F:100 % V i.e. application of vermesfluid alone at 100 % of the recommended solution concentration) but significantly (P<0.001) lower than those obtained in every other treatment including T_0 (0 % F: 0 % V i.e. the absolute control without any additives), while the maximum root yield in T_{10} was significantly (P<0.01) higher than all others except those obtained when T_{12} (75 % F:100 % V), T_6 (75 % F:25 % V) and T_7 (100 % F: 0 % V i.e. application of 600 kg/ha, the full recommended rate of NPK fertilizer) were applied. On the other hand in 2017, the root yield ranged from a minimum of 32.42 t/ha in T_8 to a maximum of 61.11 t/ha in T_{12}. Similarly, the root yield obtained in T_8 was inferior (P>0.05) to all other treatments except T_0, T_{15} and T_1 (25 % F: 25 % V), whereas, the maximum yield obtained when T_{12} was applied significantly (P<0.001) out-yielded all other treatments except T_{14} (100 % F: 100 % V). The average root yield across all treatments in 2016 and 2017 were 42.4 t/ha and 45.9 t/ha, respectively; indicating that the cassava performed better in the 2017 cropping season than the previous year. This yield differential is most probably due to a better nutritional status of the 2017 experimental site than the previous year (Table 1). All the treatments in both years had cassava yield levels described as high (>25 t/ha) (Ande *et al*., 2008) with five of them (T_{10} and T_{12} in 2016, and T_{12}, T_{14} and T_2, in 2017, respectively (Table 3) producing yields that are considered exceptionally high (>50 t/ha) (Ande *et al*., 2008). The high yield performance of the cassava roots in both years, irrespective of the treatments, is indicative of the existence of a suitable textural soil and favourable agro climatic (adequate rainfall amount and distribution) conditions within the critical 7 months establishment, rooting and tuberization/bulking period of the cassava during the trial period (Table 2). This result confirms the existence of a favourable agro climatic condition for crops in the trial zone of southeastern Nigeria (Enwezor *et al*.,1981; NRC,1990) and also the report that cassava yield is unaffected by moisture stress beyond 7 months of its establishment (El-Sharkawy *et al*., 1998: Agbaje and Akinlosotu, 2004).

Averaged across the 2 years of study, T_{12} (75% F: 100% V) significantly (P<0.001) out-yielded all other treatments including those, T_{14} and T_{10} that produced exceptionally high yield of 50.91 t/ha and 50.62 t/ha, respectively, and the application of NPK fertilizer at the full dose of 600 kg/ha (T_7) and the absolute control (T_0), the last two by 18.6 and 55.8%, respectively. Best overall, two (2) of the best three (3) yields of 57.76, 50.91 and 50.62 t/ha obtained from T_{12} (75% F: 100% V, T_{14} (100% F: 100% V) and T_{10} (75% F: 50% V) had 75% of the recommended rate of inorganic (NPK) fertilizer combined with 100% and 50% of the recommended concentration of vermesfluid, respectively. This implies that cassava farmers could combine at least 50% of the recommended concentration of vermesfluid (i.e. 2%) with 75% of NPK fertilizer (450 kg/ha).

These results suggest that application of vermesfluid at 2-4% reduced the application rate of NPK fertilizer by 25% (i.e. from 600-450 kg/ha) and is a confirmation that vermesfluid application is a cost-reducing and environmentally friendly strategy in crop production. The higher cassava yield obtained with NPK fertilizer under vermesfluid regime is in agreement with those of Ing and Ing (1999) for tomatoes and is attributable to the proper rooting, growth-stimulating and yield- enhancing potentials of vermesfluid. The non-significant yield difference between vermesfluid application at 75% and 100% of the recommended spray solution concentration, confirms the recommended application limits of 3-4% solution concentration for the product.

4. Conclusions

A 2-year average yield results under the conditions of this study, revealed that application of vermesfluid alone at the minimum and maximum recommended spraying solution concentration levels of 3 and 4%, respectively, induced similar cassava yield responses but caused a non-significant and significant reduction in yield below those of the absolute control and full dose (600 kg/ha) of NPK fertilizer, respectively. This implies the existence of suboptimal and/or imbalanced nutrition, suggesting the need for a complementary or integrated nutrient management strategy in the use of vermesfluid for sustainable cassava production. On the other hand, combined application of 75% of the full dose of NPK fertilizer with 100% of the recommended maximum vermesfluid concentration (i.e.4%) gave exceptionally high yield of cassava (57.8 t/ha), which significantly out-yielded all other treatments including the absolute control and the full dose of NPK fertilizer by 55.2% and 18.7%, respectively. This fertilization strategy, which not only maximized cassava root yield but also cut down on the inorganic {NPK} fertiliser application rate with the associated cost and environmental risk components by 25%, is recommended for adoption by farmers for sustainable cassava production on the degraded SEN Ultisol.

Table 1. Some soil properties of the experimental sites before cropping at Umudike in 2016 and 2017

Soil properties	Soil values	
Particle size distribution	**2016**	**2017**
Sand (%)	80.60	75.80
Silt (%)	6.70	10.10
Clay (%)	12.70	14.10
Textural class	SL	SL
pH (H_2O)	5.60	5.1
OM (%)	1.51	1.90
Total N (%)	0.056	0.098
Available Bray-2 P (ppm)	17.70	24.80
Exchangeable cations ($Cmolkg^{-1}$)		
K	0.067	0.122
Ca	1.60	2.40
Mg	0.80	1.60
Na	0.272	0.096
Exchange acidity (EA)	0.56	0.96
Effective cation exchange capacity (ECEC)	3.299	5.178
Base saturation (BA) (%)	83.00	81.50

Table 2. Monthly rainfall characteristics (amount and number of rainy days) for the experimental periods at Umudike

Months	Year	Rainfall Characteristics	
		Amount (mm)	**Number of rainy days**
April	2016	129	8
May	2016	278.4	16
June	2016	354.1	17
July	2016	268.7	16
August	2016	398.2	22
September	2016	312.6	15
October	2016	273.4	7
November	2016	45.0	2
December	2016	7.3	2
January	2017	51.0	2
February	2017	0.0	0
March 15,	2017	10.7	3
Total 2017/2017 for period		**2,129.4**	**110**
Average 2016/2017 for period		**185.2**	**9.6**
April	2017	188.3	8
May	2017	134.2	11
June	2017	298.1	18
July	2017	493.9	21
August	2017	222.4	17
September	2017	400.0	15
October	2017	184.2	15
November	2017	31.0	6
December	2017	0.0	0
January	2017	0.0	0
February	2017	80.1	3
March 12,	2017	9.6	3
Total for 2017/2018 period		**2,042.4**	**117**
Average for 2017/2018 period		**177.6**	**10.2**

Table 3. Fresh root yield of cassava (TME 419) as influenced by NPK 15:15:15 fertilizer and vermesfluid in 2016 and 2017 at Umudike

Treatments		Mean	fresh root yield (t/ha)	
NPK:Vermesfluid (%)		2016	2017	Two-year mean
0:0	(T_0)	37.78	36.65	37.22
25:25	(T_1)	43.92	33.62	38.77
25:50	(T_2)	42.02	51.74	46.88
50:25	(T_3)	41.40	42.60	42.00
50:50	(T_4)	40.61	47.82	44.22
25:75	(T_5)	30.18	49.26	39.72
75:25	(T_6)	49.89	45.83	47.86
100:0	(T_7)	49.12	48.25	48.69
0:100	(T_8)	35.42	32.42	33.94
50:75	(T_9)	40.94	49.46	45.20
75:50	(T_{10})	54.51	46.73	50.62
75:75	(T_{11})	41.36	46.94	44.16
75:100	(T_{12})	54.42	61.11	57.76
100:75	(T_{13})	44.80	47.74	47.27
100:100	(T_{14})	42.37	59.44	50.91
0:75	(T_{15})	29.73	34.39	32.06
LSD	(0.05)	7.181	8.10	5.44

Where LSD (0.05) = Least Significant Difference at 5%

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