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APPRAISING EFFICACY OF DIFFERENT SOURCES OF PLANT NUTRIENTS IN IMPROVING SOIL FERTILITY AND ROOT YIELD PERFORMANCE OF CASSAVA (*MANIHOT ESCULENTA* CRANTZ)

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ABSTRACT

The lingering problem of scarcity and high cost of synthetic fertilizers in Nigeria, following changes in Government policies on subsidy, procurement and distribution of inorganic fertilizers, has made inorganic fertilizers unaffordable by the resource – poor farmers, who, incidentally, are the chief food producers in Nigeria. Therefore, the need arises to critically evaluate the potential of certain organic wastes in maintaining and improving soil fertility and crop productivity. To partly meet this need, hence, this paper reports the results of a two – year trial, aimed at evaluating efficacy of different nutrient sources in improving fertility of an Alfisol and performance of cassava (*Manihot esculenta* Crantz).The experiment was laid out in a randomized complete block design with three replicates. The different sources of plant nutrients included: Poultry manure (PM); wood ash (WA); sawdust (SD); NPK (15 – 15 – 15); and control or check (C)). PM, WA and SD were applied at the rates of 10, 12, and 14 t ha^{-1}, respectively. The results obtained indicated existence of significant (P = 0.05) differences among sources of plant nutrients with respect to their effects on nutrient status of an Alfisol and cassava root yield. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in soil organic carbon (SOC) from 0.13 g kg^{-1} for C to 0.63, 0.55, 0.49 and 0.22 g kg^{-1} for PM, WA, SD and NPK, respectively. Similarly, at the end of 2012 cropping season, nutrient sources significantly increased SOC from 0.05 g kg^{-1} for C to 0.69, 0.62, 0.57 and 0.18 g kg^{-1} for the respective PM, WA, SD, and NPK. At the end of 2011 cropping season, nutrient sources significantly increased total N from 0.22 g kg^{-1} for C to 0.74, 0.60, 0.67 and 0.52 g kg^{-1} for PM, WA, SD and NPK, respectively. At the end of 2012 cropping season, nutrient sources significantly increased total N from 0.11 g kg^{-1} for C to 0.83, 0.68, 0.73 and 0.45 g kg^{-1} for PM, WA, SD and NPK, respectively. Mean values of cassava root yield data across the two years of experimentation indicated that, nutrient sources significantly increased cassava root yield from 4.18 t ha^{-1} for C to 8.91, 7.70, 7.00 and 5.46 t ha^{-1} for PM, WA, SD and NPK, respectively.

INTRODUCTION

Agricultural productivity of tropical soils is adversely affected by the inherently low fertility status of the soils, characterized by low level of activity clay, organic matter, nitrogen, phosphorus and exchangeable basic cations (Adenle, 2010; Pestov, 2012). The constraints or limitations for the utilization of the low activity clay tropical soils for continuous crop production, have necessitated increasing search for efficient soil fertility improvement practices, which in recent time, have included adoption of appropriate and adequate fertilizer packages, involving the use of organic and/ or inorganic fertilizers (Atete, 2012, Lege, 2012). The use of inorganic or mineral fertilizers in improving and maintain soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include:

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low efficiency (due to loss through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation, with resultant increased incidence of soil erosion (Kader, 2012). Asides all these limitations, high cost and occasional scarcity of synthetic fertilizers, have posed a lot of problem to their use as nutrient sources in Nigeria (Lege, 2012). The limitations of the use of mineral fertilizers to improve soil fertility has consequently informed shift of attention to the use of organic fertilizers for soil fertility improvement, especially, the highly weathered tropical soils (Arit, 2011; Kader, 2012). However, organic fertilization, too, has certain demerits of slow release and non – synchronization of nutrient release with period of growth for most short – season crops (Kiani *et al*., 2005).

Population growth, its concentration in industrialized towns and cities, and higher living standards have all resulted in a substantial increase in the quantity and diversity of waste products, particularly municipal organic solid wastes

(Adenle, 2010, Aseni, 2014). Aseni (2014), noted that, several millions of tones of domestic and industrial wastes are produced annually in towns and cities in Nigeria. These wastes, according to Adenle (2010), Atete (2012) and Aseni (2014) create a management problem, as they are left to pile up by the road side, and through environmental pollution, cause serious problem to community hygiene. However, these wastes represent a valuable resource that can be used to improve the fertility of intensively cropped soils and crop productivity, as they contain a lot of plant nutrients. In view of the increasing scarcity and high cost of synthetic fertilizers in Nigeria, following changes in Government policies on subsidy, procurement and distribution of inorganic fertilizers, consequently, resource – poor farmers, who, incidentally, are the chief food producers, can no longer afford their use to maintain soil fertility. Therefore, the need arises to critically assess the potential of certain organic wastes in maintaining and improving soil fertility and crop productivity. To partly meet this need, hence, this paper reports the results of a two – year trial, aimed at evaluating efficacy of different nutrient sources in improving fertility of an Alfisol and root yield of cassava.

MATERIALS AND METHODS

Study site: A two – year field experiment was conducted at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, during 2010 and 2011 cropping seasons. The soil of the study site belongs to the broad group Alfisol (SSS, 2003). The site had earlier been cultivated to arable crops, among which were maize, cassava, sweet potato, cocoyam, melon etc before it was allowed to fallow for four years. During the fallow period, cattle, sheep, and goat used to graze on the fallow land. At the commencement of this study, the fallow vegetation was manually cleared, after which the land was ploughed and harrowed.

Table 1. The chemical properties of the soil prior to 2011 cropping season

Soil properties	Values
pH	6.3
Organic carbon (g kg^{-1})	0.87
Total nitrogen (g kg^{-1})	0.68
Available phosphorus (mg kg^{-1})	0.60
Exchangeable bases (cmol kg^{-1}	
Potassium	0.44
Calcium	0.46
Magnesium	0.40
Sodium	0.37
Exchangeable Acidity	0.21
Effective Cation Exchangeable Capacity (ECEC)	1.88

Table 2. Nutrient composition of organic manures used in the experiment

Parameters		Values PM	WA	SD
Organic carbon	(g kg^{-1})	2.86	4.26	6.68
Total nitrogen	,,	3.99	2.07	2.63
C/N ratio		0.72	2.06	2.54
Phosphorus	,,	0.40	5.86	6.23
Potassium	,,	0.33	8.89	5.94
Calcium	,,	0.71	9.56	5.86
Magnesium	,,	0.53	8.15	4.73
Sodium	,,	0.46	4.17	3.06

Collection and analysis of soil samples: Prior to 2011 cropping season, 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 2011 and 2012 cropping seasons, another sets of soil samples were 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 were analyzed in accordance with the soil analytical procedures, as outlined by the International Institute of Tropical Agriculture (IITA) (1989). The chemical analysis of the poultry manure, wood ash and sawdust used in the experiment was also carried out (Table 2).

Experimental design and treatments: The experiment was laid out in a randomized complete block design with three replicates. The different sources of plant nutrients included: Poultry manure (PM); wood ash (WA); sawdust (SD); NPK (15 – 15 – 15); and control or check (C)). PM, WA and SD were applied at the rates of 10, 12, and 14 t ha^{-1}, respectively (Aseni, 2014), worked into the soil, three weeks before planting (WBP). The NPK 15 – 15 – 15 fertilizer was applied in two split doses, at two and four months after planting (MAP) at the rate of 400 kg ha^{-1} (Fondufe, 1995). Each plot size was 4 m x 4 m.

Planting, weeding, collection and analysis of data: Planting 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 done manually at 1, 2, 3, 4 and 5 MAP, using a hoe. At harvest (12 MAP), data were collected on cassava root yield and yield components. All the data collected were subjected to analysis of variance (ANOVA), and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

The chemical properties of the soil prior to 2011 cropping season.

Changes in nutrient status of an Alfisol at the end of 2011 and 2012 cropping seasons

Tables 3 and 4 show nutrient status of an Alfisol as affected by different nutrient sources after 2011 and 2012 cropping seasons. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in soil pH from 5.2 for C to 7.6, 8.8, 8.2 and 5.7 for PM, WA, SD and NPK, respectively. At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in soil pH from 4.8 for C to 7.8, 9.2, 8.6 and 5.2 for PM, WA, SD and NPK, respectively. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in soil organic carbon (SOC) from 0.13 g kg^{-1} for C to 0.63, 0.55, 0.49 and 0.22 g kg^{-1} for PM, WA, SD and NPK, respectively. Similarly, at the end of 2012 cropping season, nutrient sources significantly increased SOC from 0.05 g kg^{-1} for C to 0.69, 0.62, 0.57 and 0.18 g kg^{-1} for the respective

Table 3. Chemical properties of an Alfisol as affected by different nutrient sources after 2011 cropping season

Treatments (Nutrient sources	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
C	5.2e	0.13e	0.22e	0.25e	0.10e	0.12e	0.12e	0.06e
PM	7.6c	0.63a	0.74a	0.42c	0.26c	0.29c	0.23c	0.22c
WA	8.8a	0.55b	0.60c	0.55a	0.37a	0.41a	0.35a	0.32a
SD	8.2b	0.49c	0.67b	0.48b	0.31b	0.36b	0.28b	0.27b
NPK	5.7d	0.22d	0.52d	0.33d	0.19d	0.23d	0.17d	0.14d

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). C = check; PM = Poultry manure; WA = wood ash; SD = sawdust

Table 4. Chemical properties of an Alfisol as affected by different nutrient sources after 2012 cropping season

Treatments (Nutrient sources)	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
C	4.8e	0.05e	0.11e	0.18e	0.03e	0.05e	0.08e	0.03e
PM	7.8c	0.69a	0.83a	0.46c	0.31c	0.34c	0.29c	0.28c
WA	9.2a	0.62b	0.68c	0.59a	0.44a	0.47a	0.40a	0.37a
SD	8.6b	0.57c	0.73b	0.53b	0.36b	0.41b	0.34b	0.31b
NPK	5.2d	0.18d	0.45d	0.38d	0.06d	0.17d	0.13d	0.11d

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). C = check; PM = Poultry manure; WA = wood ash; SD = sawdust

PM, WA, SD, and NPK. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in total N from 0.22 g kg^{-1} for C to 0.74, 0.60, 0.67 and 0.52 g kg^{-1} for PM, WA, SD and NPK, respectively. At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in total N from 0.11 g kg^{-1} for C to 0.83, 0.68, 0.73 and 0.45 g kg^{-1} for PM, WA, SD and NPK, respectively At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in available P from 0.25 mg kg^{-1} for C to 0.42, 0.55, 0.48 and 0.33 g kg^{-1} for the respective PM, WA, SD and NPK.

At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in available P from 0.18 mg kg^{-1} for C to 0.46, 0.59, 0.53 and 0.38 g kg^{-1} for PM, WA, SD and NPK, respectively. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in exchangeable K from 0.10 cmol kg^{-1} for C to 0.26, 0.37, 0.31 and 0.19 cmol kg^{-1} for the respective PM, WA, SD and NPK. At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in exchangeable K from 0.03 cmol kg^{-1} for C to 0.31, 0.44, 0.36 and 0.06 cmol kg^{-1} for PM, WA, SD and NPK, respectively. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in exchangeable Ca from 0.12 cmol kg^{-1} for C to 0.29, 0.41, 0.36 and 0.23 cmol kg^{-1} for the respective PM, WA, SD and NPK. At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in exchangeable Ca from 0.05 cmol kg^{-1} for C to 0.34, 0.47, 0.41 and 0.17 cmol kg^{-1} for PM, WA, SD and NPK, respectively.

At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in exchangeable Mg from 0.12 cmol kg^{-1} for C to 0.23, 0.35, 0.28 and 0.17 cmol kg^{-1} for the respective PM, WA, SD and NPK. At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in exchangeable Mg from 0.08 cmol kg^{-1} for C to 0.29, 0.40, 0.34 and 0.13 cmol kg^{-1} for PM, WA, SD and NPK, respectively. At the end of 2011 cropping season, sources of plant nutrients resulted in significant increases in exchangeable Na from 0.06 cmol kg^{-1} for C to 0.22, 0.32, 0.27 and 0.14 cmol kg^{-1} for the respective PM, WA, SD and NPK. At the end of 2012 cropping season, sources of plant nutrients resulted in significant increases in exchangeable Na from 0.03 cmol kg^{-1} for C to 0.28, 0.37, 0.31 and 0.11 cmol kg^{-1} for PM, WA, SD and NPK, respectively. Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). C = check; PM = Poultry manure; WA = wood ash; SD = sawdust

Cassava root yield and yield components as affected by different nutrient sources at harvest.

Table 5 shows the effects of different nutrient sources on cassava root yield and yield parameters at harvest. Mean values of cassava root yield data indicated that, nutrient sources significantly increased cassava root yield from 4.18 t ha^{-1} for C to 8.91, 7.70, 7.00 and 5.46 t ha^{-1} for PM, WA, SD, and NPK, respectively. Similarly, nutrient sources significantly increased cassava root length from 9.07 cm for C to 16.29, 14.56, 13.16 and 11.28 cm for the respective PM, WA, SD, and NPK.

Table 5. Cassava root yield and yield components as affected by nutrient sources at harvest

Treatments (Nutrient sources)	Cassava root yield (t ha^{-1}) 2011	2012	Mean	Cassava root length (cm) 2011	2012	Mean	Cassava root diameter (cm) 2011	2012	Mean
C	4.26e	4.10e	4.18	9.11e	9.03e	9.07	6.21e	6.04e	6.13
PM	8.81a	9.00a	8.91	16.21a	16.36a	16.29	11.71a	11.83a	11.77
WA	7.51b	7.88b	7.70	14.41b	14.70b	14.56	10.25b	10.40b	10.33
SD	6.76c	7.03c	7.00	13.04c	13.27c	13.16	9.07c	9.11c	9.09
NPK	5.62d	5.29d	5.46	11.34d	11.21d	11.28	7.63d	7.56d	7.60

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). C = check; PM = Poultry manure; WA = wood ash; SD = sawdust

Nutrient sources significantly increased cassava root diameter from 6.13 cm for C to 11.77, 10.33, 9.09 and 7.60 cm for the respective PM, WA, SD, and NPK.

DISCUSSION

The chemical properties of soil in the study site, prior to cropping, indicated that the soil was slightly acidic, with a pH of 6.3. The soil organic carbon (SOC) value of 0.87 g kg^{-1} was below the critical level of 7.6 g kg^{-1} for soils in Southwestern Nigeria (Adenle, 2010; Abbet, 2012). The total nitrogen content of 0.68 g kg^{-1} was below the critical level of 1.20 g kg^{-1}, according to Abbet (2012) and Lege (2012). The K status of 0.44 cmol kg^{-1} was above the critical level of 0.38 cmol kg^{-1} (Lege, 2012). The Ca, Mg and Na contents were all below the established critical levels for soils in Southwestern Nigeria (Abbet, 2012; Liya, 2013). Relative to the control (check) treatment, the significant increases in soil pH, after cropping, adduced to sources of plant nutrients, are in consonant with the findings of Atete (2012) and Liya (2013), who noted that, application of poultry manure, wood ash, sawdust and NPK fertilizer resulted in significant increases in soil pH, after cropping.

These observations can be ascribed to significant increases in the exchangeable basic cations on the exchange sites of the soil, due to their release by the nutrient sources. The lowest soil pH value for NPK fertilizer, of all the nutrient sources, can be attributed to acidifying effects of NPK fertilizer, as a result of its acid – forming nature, due to its N and P content (Heald, 2009; Aritoff, 2012). Asides, the lowest pH value of soil in the NPK fertilizer plots, was due perhaps, to leaching of exchangeable basic cations due to low organic matter content of soil in the NPK fertilizer plots, unlike what obtained in the plots of poultry manure, wood ash, and sawdust, where the exchangeable bases would not have leached off, but would have been retained due to aggregate or structural stability of the soil, occasioned by addition of the organic nutrients. The significant increases in SOC values, observed in the plots of those nutrient sources, are in agreement with the reports of Heald (2009); Aritoff (2012) and Atete (2012), who noted significant increases in SOC, after cropping, following application of these nutrient sources. The observed increases in SOC, associated with poultry manure, wood ash, and sawdust, can be attributed to release of nutrients contained in these organic materials on decomposition, as organic matter has been noted to be a reservoir or store – house of plant nutrients (Arigbede, 2011; Galeb, 2012). The SOC value for NPK fertilizer was significantly higher than that for the control. Even though, NPK fertilizer is not an organic fertilizer, which otherwise, like its organic counterparts, would have released nutrients into the soil on decomposition, however, the higher SOC value, adduced to NPK fertilizer, relative to the control, can be attributed to higher organic matter content of soil in the NPK fertilizer plots. This is because, the NPK fertilization resulted in formation of good vegetative structure of cassava, as a result of which a lot of leaf litter was produced, and which on decomposition, resulted in formation of organic matter. This implies that, inorganic fertilization, through its positive effects formation of good vegetative structure in plants and attendant organic matter turnover, can indirectly contribute to amelioration of once – badly degraded land. Of the three organic nutrient sources (poultry manure, wood ash and sawdust), sawdust gave the lowest SOC value, after cropping, and this can be attributed to the relatively low rate of decomposition of sawdust, due to its highest lignin content, as attested to by its highest value of C/N ratio (Table2). The lowest available P value for the check or control treatment, can be attributed to the lowest pH value of soil in the check 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 significant increases in all the plant nutrients, observed under the nutrient sources, can be explained in the light of the significant increases in SOC under the nutrient sources. This is because SOC or soil organic matter (SOM) has been variously described as a reservoir of 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 SOC, total N, available P and exchangeable bases, recorded in the plots of poultry manure, wood ash and sawdust at the end of the second year (2012) cropping activities, compared to what obtained at the end of the first year (2011) cropping activities, can be adduced to the residual effects of application of poultry manure, wood ash and sawdust during the first year, coupled with additional application of these organic fertilizers in the second year.

However, for NPK fertilizer, except for P, values of these nutrients in all the plots of NPK fertilizer at the end of the second year cropping activities, were lower than what obtained at the end of the first year cropping activities, suggesting that, application of NPK fertilizer, unlike its organic fertilizer counterparts, did not produce any residual effects on soil. This implies that, soil fertility cannot be maintained or sustained on a long term basis through inorganic fertilization. The higher available P value recorded in NPK fertilizer plots at the end of the second year, compared to the first year, can be ascribed to the residual effects of application of NPK fertilizer during the first year, coupled with additional application of NPK fertilizer in the second year. This observation suggests that, the amount of P removed by cassava from the soil system during 2011 and 2012 cropping seasons was not as high as that of other nutrients, otherwise, the value of available P at the end of the second year would have been lower than that of the first year. The low P uptake of cassava, relative to other nutrients, corroborates the findings of Adenle (2010) and Atete (2012), who noted low P uptake, relative to N and K, in their studies on N, P and K nutrition of cassava. The low correlation between soil P and plant - content and yield, testifies to the low P uptake of cassava (Zorok, 2012; Aseni, 2014). These authors adduced the low P uptake of cassava to mycorrhizal association, which provides as much as 15 ppm P to the soil from fixed P by soil mycorrhiza (Zorok, 2012; Aseni, 2014). The practical implication of the low P uptake by cassava is that, P perhaps, is not a limiting nutrient element in mineral nutrition of cassava, hence, a high root yield of cassava can still be obtained in soil of inherently low P, provided other essential nutrients are not limiting. The significantly higher root yield and yield components of cassava, adduced to wood ash, poultry manure and sawdust, compared to

their NPK fertilizer counterpart, agree with the observations of Atete (2012) and Zorok (2012), who reported significantly higher cassava root yield under wood ash, poultry manure and sawdust, relative to root yield, recorded in the plots of NPK fertilizer. These observations can be ascribed to the long – term effects of these organic nutrients on improving both the physical, chemical and biological properties of the soil, unlike the inorganic fertilizers, whose effects on soil properties are shallow and short – lived (Adenle, 2010; Arena, 2012; Aseni, 2014). The significantly higher cassava root yield and yield parameters for wood ash than its sawdust counterpart, confirm the reports of Arena (2012) and Aseni (2014), who noted that, wood ash gave significantly higher cassava root yield and yield components than its sawdust counterpart.

These observations can be ascribed to the regulatory action of calcium and magnesium, contained in wood ash, on soil chemical properties, especially, reduction of soil acidity and attendant prevention of Aluminium toxicity, which would have resulted in stubbiness of cassava plants (due to interference effects of Aluminium toxicity on phosphorylation of sugars); a condition that would have consequently resulted in low cassava root yield (Zorok, 2012; Aseni, 2014). Asides, wood ash, being a lime, reduces soil acidity; a condition that results in increased availability of plant nutrients as well as promotion of microbial decomposition of soil organic matter, with resultant increased release of nutrients into the soil system (Arena, 2012; Ase, 2014). The higher cassava root yield and yield indices, obtained in the plots of those organic nutrients, at the end of the second year (2012), compared to what obtained at the end of the first year (2011), can be explained in the light of more nutrient availability during the second year cropping season, due to the residual effects of application of those organic nutrients during the first year, coupled with additional application of the organic nutrients during the second year cropping season. On the contrary, cassava root yield and yield components were lower at the end of the second year than the first year, and this can be adduced to declined soil fertility during the second year, as a result of nutrient removal by cassava during the first year cropping season. These observations testify to the assertions of Aseni (2014) and Ase (2014), who established that, soil fertility and crop yield tend to decline under continuous cultivation, with or without application of inorganic soil amendment(s).

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