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Changes in some Soil properties, Growth and Yield of Tomato as Affected by the Application of Poultry Dropping and NPK Fertilizer on a Humid Alfisol in Southwestern Nigeria

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Abstract

The effect of integrating poultry droppings and NPK 15-15-15 fertilizer on soil fertility and tomato yield were studied to investigate the effect of organic and inorganic fertilizer on soil properties, growth and yield of tomato. The experiment was laid out as a randomized complete block design (RCBD) with four treatments and three replicates. The experiment was conducted at the teaching and research farm of Joseph Ayo Babalola University, Ikeji-Arakeji, Nigeria between June to September in 2016 and August to November 2016. A 12m × 15m plot was demarcated for the experiment. The plot was partitioned into three blocks of 4m×15m. Each 4m×15m block was further divided into four smaller plots of 3m x 3m separated by buffer of 1.0m wide. The treatments were:

Control; NPK -15-15-15 at 250kg ha^{-1}; Poultry droppings (PD) at 5.0 t ha^{-1}; and NPK 15-15-15 (125 kg) + PD (2.5 t) ha^{-1}.. At four and six weeks after transplanting (WAT), height, diameter and biomass of the tomato plant were determined. At maturity (six weeks after transplanting) the weight of tomato fruit was determined. The combined NPK + PD treatment recorded the highest values for the height, diameter and biomass (fresh and dry) of the plant. The yield of tomato was also highest in the plot treated with NPK + PD. Soil properties were significantly improved by applying the treatments. In conclusion, integrating poultry droppings and NPK 15-15-15 has more benefits over NPK or poultry droppings alone.

Keywords: Fertility; soil nutrients; poultry droppings; integrated nutrient management.

1. INTRODUCTION

Combining compost and ashes may play a significant role for tropical soil security by mitigating nutrients leaching (Agegnehu, Nelson, & Bird, 2016). Besides, compost is also known to increase plant yield through the addition of nutrients (Mbau, Karanja, & Ayuke, 2014; Zhang *et al*., 2016). Additionally, letting some trees within the fields could also raise the soil organic matter content through littering (Nair, 2013). Food is one among the most important basic necessities of man. For Nigeria to meet the millennium development goal in food production, food including tomato must be readily available. Low soil fertility could threaten the security of food production and supply. Soil fertility is a major overriding constraint that affects all aspects of crop production ([Mbah, 2006). In the past years, inorganic fertilizer was advocated for crop production to ameliorate low inherent fertility of soils in the tropics. In addition to being expensive and scarce, the use of inorganic fertilizer has not been helpful in intensive agriculture because it is often associated with reduced crop yield, soil acidity and nutrient imbalance (Ojeniyi, 2000, Ano and Agwu, 2005 and Agbede *et al*, 2008). The need to use renewable forms of energy and reduce costs of fertilizing crops has revived the use of organic fertilizers worldwide

(Ayoola and Adeniyan 2006). Large quantities of organic wastes such as poultry manure are available especially in urban centers and are an effective source of nutrients for vegetables such as tomato [Adediran, *et al*, 2006]. Soil fertility status varies considerably with different ecological zones. In fact, even in the same zone, there are micro-differences in soil characteristics. The crop yield response to organic waste is highly variable and depends on the types of wastes, crop type and species, soil type and climate conditions [Adediran, et al 2006]. Akanni and Ojeniyi, 2007 carried out a study in the rainforest zone of southwest Nigeria and recommended 20 t ha-1 poultry manure for tomato production. [Adediran, *et al* 2006] also found that poultry manure at 20 t ha^{-1} gave the highest tomato yield in the rainforest region of southwestern Nigeria. Furthermore, the benefits of using organic materials have not been fully utilized in the humid tropics, partly due to the huge quantities required to satisfy the nutritional needs of crops, transportation and handling costs [Ayoola and Adeniyan 2006]. High and sustained crop yield can be obtained with judicious and balanced NPK fertilization combined with organic matter amendment [Osundare, 2004].

Objective

In the light of these issues, a study was conducted to determine the growth and yield of tomato as influenced by different levels of poultry manure, NPK fertilizer and the integration of NPK fertilizer and poultry manure in a tropical Alfisol, Southwest Nigeria.

2. MATERIAL AND METHODS

2.1: Site Description

The experiment was conducted on the teaching and research field plot of the College of Agricultural Science of Joseph Ayo Babalola University, Ikeji Arakeji which lies between latitude 07º16^{1} and 07º 18^{1} and longitude 05º 09^{1} and 05º 11'^{1} E between June to September and in August to November, 2016. The area is characterized by a tropical climate. The study area is situated in the humid tropical forest zone of Nigeria. It has an annual average rainfall of between 1500-1800mm and relative humidity of between 80-85% annually [Meteorological data, Meteorological Dept, Federal University of Technology, Akure, Nigeria, 2011]. It has a gentle undulating elevation of about 1150m-1250m above sea level [Olojugba, 2011].

2.2: Experiment Design

The experiment was laid out as a randomized complete block design (RCBD) with four treatments and three replicates. A 12m × 15m plot was demarcated on the teaching and research farm of Joseph Ayo Babalola University Ikeji-Arakeji, Nigeria. The plot was partitioned into three blocks of 4m × 15m separated by 1.0m buffer. Each 4m × 15m block was further partitioned into four 3m x 3m plots separated by buffer of 1.0m wide. The treatments were: Control (no treatment application); NPK -15-15-15 at 250 $kgha^{-1}$ (which supplied 37.5 $kgha^{-1}$N, 37.5 $kgha^{-1}$P and 37.5 $kgha^{-1}$K respectively); Poultry droppings (PD) at 5.0 t ha^{-1}(which supplied 112.5 kgh^{-1}N) and NPK 15-15-15 (125 $kgha^{-1}$) + PD (2.5 t) ha^{-1} (which supplied 64.2 $kgha^{-1}$).

All treatments were allocated to the plots in each block at random. PD was applied at the beginning before transplanting by spreading it on the plot while NPK was applied one week after transplanting using ring method and at a distance of 10 cm from the plant. However, control plot did not receive any amendment. Weeding, diseases and pests control etc were done at appropriate time.

Tomato seeds (var. NC82B) were obtained from National Horticultural Research Institute (NIHORT) in Ibadan, Nigeria.

Seedlings were raised in boxes for four weeks before being transplanted to the experimental plot. In the nursery where no treatment was applied, shade was provided against the direct impact of solar radiation while the boxes were kept weed free and watered every day. Prior to seedling transplant into the field, the soil was heavily watered. Vigorous seedlings were transplanted on the experimental plot at 3 weeks old after a heavy rainfall, and were planted at a distance of 60 cm x 30 cm giving a total of 55,556 plants/ha and 50 plants/plot.

2.3: Poultry Droppings Collection

Poultry droppings were collected from the layer◎s battery cage system. Contaminants such as feathers and raw feeds were carefully sorted out, heaped and allowed to ◎cake-up◎ and dried for two weeks, ground and taken to laboratory for analysis.

2.4: Data Collection & Analysis

2.4.1: <u>Plant sample collection</u>

This was done at four and six weeks after transplanting (WAT) and treatment application, plant height and diameter of ten randomly selected plant stems were taken with meter rule and veneer caliper.

Also four plants were uprooted per plots, per treatment and washed and bulked into composite samples. Fresh weights of the samples were taken. Sub-samples of each treatment per plot were oven dried at 100^{o}C for 48hrs to constant weight to determine dry matter content. Sub-sample dry weight was used to compute the total dry weights, using the relationship [Adeboye, Ajadi, 2006]:

Sample dry wt. (g) = Sample fresh wt (g) x sub-sample dry wt. (g) / sub-sample fresh wt. (g).

At maturity (six weeks after transplanting WAT), ten plants were randomly selected from each plot, harvested and weighed and calculated as tone per ha based on this formula [11]: $Pp = \{(B + b) (L + l) / lb\} \times N$ (11), where

Pp = Plant population, L = Length of the farm, B = Breadth of the farm, l = Length of spacing of the farm, b = Breadth of spacing of the farm and N = Number of fruits per farm stand

2.4.2: Soil Sample Collection and Analysis

Soil samples were previously taken randomly and analyzed to know the nutrient status of the area using soil auger to the depth of 0-15cm. At planting, five soil samples in each plot were taken. Samples from each plot were bulked and composite were collected and taken to the laboratory for analysis.

2.4.2.1: ***Particle Size Analysis***

This was done by hydrometer method [Bouycous, 1951] using sodium hexametaphosphate (calgon) as dispersing agent.

2.4.2.2: ***Chemical Properties***

The pH of the soil samples was determined using a glass electrode pH meter in 1:2 soil water ratios [Crockford and Norwell, 1956].

Organic carbon content of the soil samples were determined by dichromate oxidation method [Walkley and Black, 1934]. The percentage organic matter content of the samples was calculated by multiplying the values of organic carbon by a factor of 1.724 based on the assumption that soil organic matter contains 58% carbon [Allison, 1982].Total N was determined by the Kjeldahl method [Bremner, 1996]. Available phosphorus was extracted by Bray-1-method [Bray and Kurtz, 1945] and the P in the extract was determined calorimetrically. Exchangeable Ca, K, Mg and Na were extracted with 1.0N NH40AC (Ammonium acetate) using a soil solution volume ratio of 1:10 [Jackson, 1962]. K and Na in the extract were read using flame photometer while Ca and Mg were determined by Atomic Absorption spectrophotometer. The exchangeable acidity was determined from 0.1N KCl extracts and titrated with 0.1N HCl [Maclean, 1954]. Cation exchange capacity was determined by the summation of NH4OAC ◎ extractable cations plus 1.0N KCl extractable acidity.

2.4.2.3: ***Proximate analysis of Poultry Droppings***

pH was determined using a glass electrode pH meter in 1:2 soil water ratios [Crockford and Norwell, 1956]. Organic carbon content of the soil samples were determined by dichromate oxidation method [Walkley and Black, 1934]. The percentage organic matter content of the samples was calculated by multiplying the values of organic carbon by a factor of 1.724 based on the assumption that soil organic matter contains 58% carbon [Allison, 1982].Total N was determined by the Kjeldahl method [Bremner, 1996]. Available phosphorus was extracted by Bray-1-method [Bray and Kurtz, 1945] and the P in the extract was determined colourimetrically. Potassium content was determined by method described by [Jackson,1962].

2.5: Economic analysis

Economic analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Naira (N) based on the procedure of [CIMMYT, 1988]

2.6: Statistical Analysis

Data were subjected to analysis of variance using the general linear model procedure (GLM) for randomized complete Block design (RCBD) in SAS [SAS Institute, 2005]. Analysis of variance was computed to determine the significance of treatments. Mean separation was done using Duncan◎s New Multiple Range.

3.0: RESULTS

3.1.1: Pre-planting Physical and Chemical Properties of the Soil of the Experimental Site

The soil of the area was slightly acidic and had low percentage of organic carbon (Table 1). Also, the total soil nitrogen and available soil phosphorus of the area were low. The texture of soil in the area was sandy loam. Calcium, magnesium, potassium, and effective cation exchange capacity (ECEC) were low which the value of exchangeable acidity was fairly high.

Table 1: Pre-planting physico-chemical properties of soil of the Experimental Site

Soil Properties	Values
pH (water)	5.9
Organic Carbon	1.46
Organic Matter (%)	2.52
Total nitrogen (%)	0.067
Available P (mg/kg)	3.44
Sand (%)	64
Silt (%)	24
Clay (%)	12
Calcium (cmol/kg of soil)	0.8
Magnesium (cmol/kg of soil)	0.35
Potassium (cmol/kg of soil)	0.15
Sodium (cmol/kg of soil)	0.17
Exchange acidity (cmol/kg of soil)	1.36
ECEC	2.83

The textural class based on the table is Sandy loam

ECEC: effective cation exchangeable capacity

3.1.2: Proximate Analysis of Poultry Droppings Used as Amendment

The value of pH of the poultry droppings shows that it was alkaline with a value of 8.3. The moisture content value was 28.9%, while the value of organic carbon was 12.6%. The nitrogen (N), phosphorus (P) and potassium (K) were 2.25%, 697.06 $mgkg^{-1}$and 1387.70 $mgkg^{-1}$ respectively (Table 2).

Table 2: Proximate analysis of Poultry Droppings Used as Amendment.

Parameters	pH	OC %	OM %	Water %	N%	P mg/kg	K mg/kg
Values	8.4	12.6	21.72	28.9	2.25	697.06	1387.7

OC = organic carbon, OM = organic matter, N = nitrogen content, P = phosphorous content and K = potassium content.

3.1.3: Effect of Organic Matter and NPK Fertilizer on the Height, Diameter and Yield of Tomato

Table 3 shows some growth and yield parameters of the tomato plant.. At four weeks after transplanting (WAT), the plant height values ranged from 39.44cm to 45.52cm in the control and the NPK+PD treatments respectively. The diameter values ranged from 1.36cm for the control treatment to 1.66cm for the NPK+PD treatment. There was no significant difference in the height of NPK and PD as well as NPK+PD and PD. Diameter showed no significant difference between PD and NPK+PD.

At six weeks after transplanting (WAT), the values of height ranged from 45.04cm in control plot to 50.09cm in NPK + PD plot while for the diameter, the NPK+PD had the highest value of 2.05cm, while the lowest value of 1.43cm was recorded from the control plot. However, there was no significant difference ($P \leq 0.05$) between PD and NPK+PD. In the same vein, there was no significant difference ($P \leq 0.05$) between NPK and PD. The fruit yields of tomato were more in the plot mulched with NPK + PD with the value of 2.65 t/ha while the least value of 0.82 t/ha was recorded in the control plot.

Table 3: Effect of organic and inorganic fertilizer on some growth and yield parameters of tomato plant

	4 Weeks		6 Weeks		Final Yield
Treatments	Ht. (cm)	Dia. (cm)	Ht. (cm)	Dia. (cm)	t/ha
Control	39.44^{c}	1.36^{c}	45.04^{c}	1.43^{c}	0.82^{d}
NPK+PD	45.52^{a}	1.61^{a}	50.09^{a}	2.05^{a}	2.65^{a}
PD	44.82^{ab}	1.57^{a}	49.52^{ab}	1.85^{b}	1.67^{b}
NPK	43.87^{b}	1.44^{b}	49.04^{b}	1.83^{b}	1.32^{c}

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$.

3.1.4: Effect of Organic Matter and NPK Fertilizer on fresh and Dry Matter of tomato

At four weeks after transplanting (WAT) the values of fresh weight of the whole plant ranged from 0.27t/ha in the control plot to 0.59t/ha in the NPK + PD plot, the dry weight values ranged from 0.16t/ha to 0.43t/ha in the control and the NPK + PD respectively (Table 4).

At six weeks after transplanting (WAT), the fresh weight ranged from 0.30t/ha in the control plot to 0.61t/ha in the NPK + PD plot. The dry weight ranged from 0.14t/ha to 0.44t/ha in the control and the NPK + PD plots respectively. There were no significant differences among the NPK + PD, PD and NPK treatments for the fresh weight at four weeks; also no significant differences were found between NPK + PD and NPK treated plots and the PD and NPK plots for the dry weight of the plant.

Table 4: Effect of organic and inorganic fertilizer on fresh and dry matter of tomato plant at 4 weeks and 6 weeks after transplanting (WAT).

Treatments	4 weeks fresh wt. (t/ha)	dry wt. (t/ha)	6 weeks Fresh wt. (t/ha)	dry wt. (t/ha)
Control	0.27[c]	0.16[c]	0.30[c]	0.14[c]
NPK+PD	0.59a	0.43a	0.61a	0.44a
PD	0.40[ab]	0.20[b]	0.42[ab]	0.20[b]
NPK	0.54[a]	0.36[ab]	0.56[a]	0.37[ab]

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$

PD: poultry droppings

3.1.5: Effect of Organic Fertilizer and NPK Fertilizer on Some Soil Chemical Properties

The pH values ranged from 5.6 in the control plot to 6.05 in the PD plot (Table 5). The PD plot had the highest value of organic carbon (OC) of 1.85% while 1.46% was recorded in the control plot. Total nitrogen values ranged from 0.061% in the control plot to 0.077% in the NPK + PD plot. The control plot had the least value of 2.97mg kg^{-1} while the highest value of available phosphorus was recorded in the NPK + PD plot with a value of 17.42mg kg^{-1}. The NPK + PD plot had the highest value of 1.5mg kg^{-1} for Ca with the least value of 0.23mg kg^{-1} recorded from the control plot. Magnesium value was lowest (0.32mg kg^{-1}) in the control plot and highest (0.96mg kg^{-1}) in the NPK + PD plot. Potassium values ranged from 0.15 mg kg^{-1} in the control plots to 0.47mg/kg in the plot mulched with NPK + PD. Sodium had the highest value of 0.37mg kg^{-1} of soil in the NPK + PD plot and the least value of 0.13mg kg^{-1} of soil in the control plot. The effective cation exchange capacity was low in the entire area with the least value of 2.2mg kg^{-1} of soil recorded in the control plot while the highest value of 4.67mg kg^{-1} was recorded in the NPK + PD plot.

There was no significant difference between NPK and NPK + PD for pH (H_2O).Total nitrogen showed no significant difference in NPK and PD. There was no significant difference in calcium value between PD and NPK plots. There was no significant difference in the magnesium value in NPK + PD and PD plots.

Table 5: Effect of organic and inorganic fertilizer on chemical properties

	pH(H_20)	**OC**	**N**	**P**	**Ca**	**Mg**	**K**	**Na**	**EA**	**ECEC**
Treatments				mg/kg	Cmol/kg of soil					
CONTROL	5.6^c	1.46^c(%)	0.061^c(%)	2.97^d	0.23^c	0.32^c	0.15^c	0.13^c	1.37^b	2.2^d
NPK	5.6^c	1.43^d(%)	0.069^b(%)	15.24^b	1.26^b	0.66^b	0.43^{ab}	0.32^{ab}	1.38^a	4.0^c
NPK+PD	5.95^{ab}	1.67^b(%)	0.077^a(%)	17.42^a	1.5^a	0.96^a	0.47^a	0.37^a	1.37^b	4.67^a
PD	6.05^a	1.85^a(%)	0.071^b(%)	15.91^b	1.17^b	1.06^a	0.42^b	0.32^{ab}	1.37^b	4.34^b

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$.

PD: poultry dropping: OC: organic carbon, N: nitrogen, P: phosphorus, Ca: calcium, Mg: magnesium, K: potassium, Na: sodium, EA: exchangeable acidity, ECEC: effective cation exchangeable capacity.

3.1.6: Effect of Organic Fertilizer and NPK Fertilizer on the Profitability of the tested Technologies

Table 6 shows the profitability analysis of the tested technologies. The table indicated the net profit of N192610, N313935, N645123 and N398820 in the control, NPK, NPK + PD and PD plots respectively.

Table 6: Treatments effect on the profitability of tomato production

Treatment	Yield (t/ha)	Value of yield (N)	Cost of production (N)	Net profit (N)
Control	0.82[d]	205000[d]	12390[d]	192610[d]
NPK	1.32[a]	330000[c]	16065[c]	313935[c]
NPK+PD	2.65[b]	662500[a]	17377.5[b]	645123[a]
PD	1.67[c]	417500[b]	18690[a]	398820[b]

Means on the same column followed by the same letter are not significantly different at $P \leq 0.05$.

NB: 1 US$= N 158.00 Nigeria Naira

1 ton of fresh tomato = N 250 Nigeria naira (US$ 1.6)

3.2: DISCUSSION

3.2.1: Pre-planting Physico-Chemical Properties of Soil of the Experimental Site

The texture of the area was sandy loam and this might be attributed to the lithology of the parent material [Olojugba, 2010]. Nitrogen, phosphorus, potassium, calcium, magnesium and sodium were low in the study area. This might be due to over cropping, leaching of soluble cations, soil erosion and lack of proper land management practices in the area. The acidic nature might be due to leaching of soluble cations. The low value of organic carbon might be due to the continuous cropping without the addition of organic matter [Enwezor, *et al*, 1981].

3.2.2: Proximate Analysis of Poultry Droppings Used as Amendment

Poultry droppings is an excellent organic soil amendment due to its high organic carbon (C) contents as observed in the plots amended with poultry droppings. The high pH value of the PD shows that it is capable of reducing soil acidity as reflected in the plot amended with poultry droppings. The inorganic forms of N (NH_4-N and NO_3-N) account for 14% of the total N and are readily available for plant uptake. The remaining portion of the total N (76%) is an organic form and must be mineralized prior to becoming available for plant uptake [Sharpley and Moyer, 2000]. Most of the P in poultry dropping is inorganic [Sharpley and Moyer, 2000], with the remainder in organic forms that can become plant available upon mineralization. These accounted for the increased NPK contents in the plots amended with poultry droppings and PD + NPK.

3.2.3: Effect of Organic Manure and NPK on the Height, Diameter, Dry Matter and Yield of Tomato

All the treatments increased the plant height, diameter, fresh matter, dry matter and yield as compared to the control at four and six weeks after transplanting (WAT) of seedlings. The highest height and highest diameter were obtained from the plot mulched with Poultry droppings + NPK. The same trend was also recorded for the fresh and dry matter weights. The trend might be due to the high amount of nutrients in the NPK + PD treatment. This was in agreements with the findings of [Opala, 2011] attributed this to the higher nutrients released by NPK + PD plot.

On the yield, NPK + PD gave the highest yield which might be attributed to the supply of large quantities of needed nutrients and the improvement in the physico-chemical properties of the soil. This finding was in tune with the earlier assertion of [Upawansa, 1997]. He was of the opinion that the integrated nutrients management has combined effect on soil conservation, nutrient enhancement and biological activities improvements.

3.2.4: Effect of Organic Manure and NPK Fertilizer on Some Soil Chemical Properties

There were significant differences in soil pH, PD and NPK + PD plots increased soil pH over the control and NPK plot. This might be due to the specific adsorption of humic materials and organic acid (the products of decomposition of organic materials) onto hydrous surfaces of aluminum and iron oxides by exchange with the corresponding release of OH^- [Opala, 2011]. The significantly higher value of organic carbon in the plot mulched with PD might be due to the higher level of organic materials in the treatment. The significantly higher soil nitrogen in the plots mulched with PD and NPK + PD might be due partly to the higher nitrogen content in the poultry dropping and the NPK component [Ncube, *et al*, 2007] and also the high organic matter content, which has been identified as a store house for nitrogen[Schlecht, *et al*, 2006]. In the same vein, the significantly higher available phosphorus in the PD as well as NPK + PD plots might be due to the distribution of soil organic matter as well as the release of phosphorus from poultry droppings and NPK. Also in the same vein, the significantly higher calcium, magnesium, potassium and sodium levels in the plots treated with poultry droppings (PD) and NPK + PD might be due to higher percentage of these minerals from the treatments and as a result of the effect of PD on the soil organic matter, which serves as a store house for these minerals and prevent leaching [Opala, 2011]. The fairly low exchangeable acidity (EA) in the PD and NPK + PD might be due to higher exchangeable cations (Ca, Mg, K, Na); the presence of these cations reduced exchangeable acidity and subsequently increased pH. Effective cation exchange capacity (ECEC) was higher in the plots treated with PD and NPK + PD as a result of higher cations from these treatments (PD and NPK + PD).

3.2.5: Effect of Organic Fertilizer and NPK Fertilizer on the Profitability of the tested Technologies

Low net benefit recorded from the control plot might be due to the low yield from this plot. PD plot could not return much net benefit as a result of fairly high labour requirement associated to it.

NPK + PD gave the highest net benefit due to the substantial yield as well as fairly low non-labour cost associated with it.

4.0: CONCLUSION AND RECOMMENDATIONS

Soil quality improvement and crop production on farm remain an important issue for agricultural research. This work has contributed to knowledge on the importance of using both organic manure and mineral fertilizer. It was shown that there is a potential to improve yield of tomato by combining poultry dropping and NPK fertilizer. It was established in this work that the combination of poultry droppings and NPK fertilizer increased the growth and fruit yield of tomato. Also, there was increase in soil nitrogen, organic carbon, calcium, magnesium, phosphorus, potassium and cation exchange capacity. Furthermore, exchangeable acidity and soil pH were reduced and increased respectively. The management of nutrient resources is essential to improve soil productivity and crop performance; it is therefore recommended that further investigations into the effect (i.e. crop yield and nutrient absorption) of applying poultry dropping direct to the soil and twice in a crop cycle be carried out.

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