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ENHANCED SOIL CHEMICAL PROPERTIES, NUTRIENT UPTAKE AND DRY MATTER YIELD IN A MINERAL AND ORGANIC FERTILIZATION OF GINGER (*Zingiber Officinale* Roscoe) IN UMUDIKE, SOUTHEAST NIGERIA

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Abstract
Field studies were carried out in 2018 and 2019 at the National Root Crops Research Institute Eastern Farm, Umudike to explore the enhancement of soil chemical properties, nutrient uptake and dry matter yield in a mineral and organic fertilization of ginger (*Zingiber officinale* Roscoe) in Umudike, Southeastern Nigeria. There were seven treatments consisting of sole and combinations of poultry manure, rice mill waste and NPK 15:15:15 with a rate of 45 kg N ha^{-1} regarded as 100%. The treatments were as follows: 100% NPK 15:15:15 (45 kg N ha^{-1}), 100% poultry manure (45 kg N ha^{-1}), 100% rice mill waste (45 kg N ha^{-1}), 50% NPK 15:15:15 (22.5 kg N ha^{-1}) + 50% poultry manure (22.5 kg N ha^{-1}), 50% NPK 15:15:15 (22.5 kg N ha^{-1}) + 50% rice mill waste (22.5 kg N ha^{-1}), 50% NPK 15:15:15 (22.5 kg N ha^{-1}) + 25% poultry manure (11.25 kg N ha^{-1}) + 25% rice mill waste (11.25 kg N ha^{-1}) and control. They were arranged in a randomized complete block design with three replications. Ginger variety (UG I) was used for the experiments. Soil chemical properties and nutrient uptake (N, P and K) of the ginger rhizome after harvest were determined. The dry matter yield at harvest was equally determined. Results showed that the application of the treatments significantly ($P < 0.05$) increased soil chemical properties with the application of 50% NPK + 50% poultry manure giving highest values for most of the parameters determined in the two planting seasons. The 50% NPK + 50% poultry manure significantly reduced soil acidity from a very strong acidity level of 4.80 and 4.70 (initial values before experiment) to 5.30 in each year. It increased total N from 0.98 to 1.30 g kg^{-1} in 2019, increased available P from 18.50 to 23.50 mg kg^{-1} in 2018, calcium from 3.6 and 3.20 cmol kg^{-1} to 4.40 and 4.00 cmol kg^{-1} for 2018 and 2019 respectively, effective cation exchange capacity from 6.76 and 5.95 cmol kg^{-1} to 7.40 and 7.02 cmol kg^{-1} and base saturation from 81.66% and 78.49% to 96.76% and 90.88% for 2018 and 2019. Nutrient uptake of nitrogen, phosphorus and potassium in the ginger rhizome were significantly ($P < 0.05$) increased by the treatments. The treatment combination of 50% NPK + 50% poultry manure gave the highest nutrient uptake in N, P and K for the two planting seasons. The dry matter yield of ginger was significantly ($P < 0.05$) increased across all the treatments when compared with the control. The highest dry matter yield of 12 058.9 kg ha^{-1} in 2018 was obtained from the combination of 50% NPK + 50% poultry manure. While in 2019, the highest dry matter yield of 9 868.4 kg ha^{-1} was obtained from the plot treated with 100% poultry manure which did not show any statistical difference from the yield of 9 702.3 kg ha^{-1} obtained from plot treated with 50% NPK + 50% poultry manure. The use of 50% NPK + 50% poultry manure was recommended for enhanced soil chemical properties and better yield in the study areas.

Keywords: Dry matter yield, Ginger, NPK fertilizer, Nutrient uptake, Organic manure, Soil chemical properties

Introduction

Zingiber officinale Roscoe popularly known as ginger is a plant that produces an underground rhizome which is an important raw material for medicinal and pharmaceutical industries throughout the world (Schweitzer and Rio, 2007). Ginger requires well drained soils rich in nitrogen, phosphorus and potassium. Adequate soil nitrogen, phosphorus and potassium are essential nutrients which can be supplied by organic or inorganic fertilizer sources (Moritsuka *et al.* 2001). Although inorganic fertilizers can be used to increase crop yields, replenish soil nutrients and nutrient availability, their use in tropical agriculture is limited due to their scarcity, high cost, nutrient imbalance and soil acidity (Akande *et al.*, 2010). Furthermore, continuous use of inorganic fertilizers in crop production affects soil structure and may even lead to lower yield of crops if not properly regulated and managed (Akande *et al*., 2010). The work of Dauda *et al.* (2008) has shown that organic manures can serve as a better alternative to inorganic fertilizers in terms of improving soil structure; fertility and productivity as they are known to supply nutrients to crops, improve soil physical and chemical conditions through increased organic matter. Organic fertilizer has been shown to sustain crop yield, provide better nutrient recycling, soil productivity, and safe guard the health of the soil and the seed (El-Shakweer *et al.*, 1998; Belay *et al.,* 2001). In addition, soil organic matter also performs a biological function by providing carbon - an energy source for soil microbes (Kumbhar *et al.,* 2007). The effect of inorganic fertilizer on highly weathered and low nutrient soils without any compensatory organic input sources has been reported to have limited residual effects on crop production (Okigbo, 2000). Organic fertilizers like poultry manure and rice mill waste are high in nitrogen, phosphorus and potassium which is good for root and tuber crops like ginger. On the other hand, organic amendments alone may not offer sufficient nutrient supply to meet plant demand (Palm *et al.,* 1997; Gentile *et al*., 2011; Bedada *et al*., 2014). One way to counter this soil fertility problem is by Integrated Soil Fertility Management (ISFM), a technique that makes use of both organic and inorganic resources resulting in greater yield response and better nutrient storage (Bedada *et al*., 2014; Ewusi-Mensah *et al*., 2015). This study aims at evaluating the sole effects of mineral and organic manures and their combinations with mineral fertilizer on the changes in soil chemical properties with a view to knowing how such changes can affect the nutrient uptake and dry matter yield of ginger in Southeastern Nigeria.

Materials and Methods

Study Area

The field experiment was conducted in 2018 and 2019 at the National Root Crops Research Institute Eastern Farm, Umudike, Abia State. Umudike is located on latitude 05^{0}27^{1} North and longitude 07^{0}32^{1} East with an altitude of 123 meters above sea level. The locations had been under cultivation for some time. Umudike is located within the tropical rainforest zone with a mean rainfall range of 1512 – 2200 mm, which is distributed over nine to ten months in bimodal rainfall pattern. These are the early rain (April-July) and late rain (August-October) with five months of dry season and a short dry spell in August. The monthly minimum air temperature ranged from 20 ^{0}C to 24 ^{0}C while the monthly maximum air temperature ranged from 28 ^{0}C to 35 ^{0}C. (NRCRI, Umudike Meteorological Station, 2014). Both soils were classified as Typic Paleudults (Chukwu, 2013).

Soil Sampling, Planting Material and Amendments

Soil samples were collected randomly at 0-20 cm depth from the two years trial before the commencement of the experiments, bulked and a composite sample was taken for analysis. At the end of the experiment, three auger samples were taken per plot at the same depth, bulked and a composite sample was taken for analysis. The composite soil samples were air dried and pass through a 2 mm sieve for laboratory analysis. Ginger (*Zingiber officinale* Roscoe) UG 1 variety was obtained from National Root Crops Research Institute, Maro sub-station, Kaduna State. The poultry manure was collected from a commercial poultry farm in Umudike. Rice mill waste was obtained from Bende Local Government Area of Abia State, while the NPK fertilizer was purchased from an open market in Umuahia town.

Experimental Layout and Treatments

The study areas were mapped out into 21 experimental plots. Each plot measured 1 × 2 m with inter plot distance of 0.5 m and inter replicate distance of 2 m. The experimental plots were manually tilled into beds. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. The full dose of N used was 45 kg ha^{-1} for ginger production was regarded as 100%. The rate of organic manure used was based on N equivalent. In both 2018 and 2019 studies, the treatments were:

1. Control (no fertilizer)
2. 100% NPK 15:15:15 (45 kg N ha^{-1})
3. 100% Poultry manure (PM) (45 kg N ha^{-1})
4. 100% Rice mill waste (RMW) (45 kg N ha^{-1})
5. 50% NPK (22.5 kg N ha^{-1}) + 50% PM (22.5 kg N ha^{-1})
6. 50% NPK (22.5 kg N ha^{-1}) + 50% RMW (22.5 kg N ha^{-1})
7. 50% NPK (22.5 kg N ha^{-1}) + 25% PM (11.25 kg N ha^{-1}) + 25% RMW (11.25 kg N ha^{-1})

Planting and Data Collection

The poultry manure and rice meal waste were incorporated to specified plots one week before planting as stated by Iren *et al.* (2011). One seed of ginger was planted per stand at a spacing of 0.2 m by 0.2 m (0.04 m^{2}) giving a plant population of 250, 000 plants ha^{-1}. The NPK fertilizer was applied to specified plots in two doses (split application) 6 and 12 weeks after planting. Mulching was done between 24 to 48 hours after planting with dry leaves of guinea grass (*Panicum maximum*) at 50 t/ha. The farm was kept weed-free throughout the period of the experiment. The ginger plant was planted in the month of May for 2018 and 2019 planting seasons and it lasted for eight months in the field. Weights of the fresh rhizomes were taken at harvest and the dry matter yield and nutrient uptake were determined.

Laboratory Analyses

The particle size distribution was done using Bouyoucos hydrometer method (Sheldrick and Wang, 1993). Soil pH was determined using a ratio of 1: 2.5 in soil water medium and read with a digital pH – meter (Ibitoye, 2006). Soil total nitrogen was determined by the micro – kjeldahl method (Bremner, 1996). Organic carbon content was determined by Walkley and Black wet dichromate oxidation method as modified by Nelson and Sommers (1996). The available phosphorus was extracted by the Bray – 2 extractant (Bray and Kurtz, 1945). The exchangeable bases (Ca^{2+}, K^{+}, Mg^{2+} and Na^{+}) were extracted with IN NH_4OAc, using a soil: solution volume ratio of 1:10. The K and Na in the extract were read using a flame photometer, while Ca and Mg were determined by EDTA titration method (IITA, 1989). Exchangeable acidity (H^{+} and Al^{3+}) were determined by extraction with IN KCl and titration with IN HCl (Hendershot and Lalande, 1993) Effective cation exchange capacity was calculated as the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) and exchangeable acidity (H^{+} and Al^{3+}). Total exchangeable base was calculated as the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}). The percentage base saturation was determined as the total exchangeable bases (TEB) divided by the effective cation exchange capacity (ECEC) and multiplied by 100.

Ginger Rhizome and Organic Manure Analysis

The fresh samples of the ginger rhizome at harvest, at different treatment levels were oven dried at 70^{0}C for 72 hours and milled. 0.2g each of the powdered ginger at different treatment levels and the poultry manure and rice mill waste used for the experiment were extracted using sulphuric acid and perchloric acid. The N, P and K in the extract were determined using standard methods listed above.

Statistical Analysis

Analysis of variance was carried out on each of the observations using GENSTAT Statistical package. Significant means were separated using Duncan's New Multiple Range Test (DNMRT) at 5% level of probability.

Results and Discussion

Physical and Chemical Properties of the Soil before the Experiment

The properties of the soils used for the study are presented in Table 1. The soils of the experimental sites were Loamy sand in texture. The soils were strongly acidic with pH of 4.80 and 4.70 for 2018 and 2019 respectively. This is an indication of low exchangeable bases in the soil. The organic carbon of the two sites were 9.20 g $kg^{-1}$and 11.00 g kg^{-1}, this is lower than the critical level of 20.00 g kg^{-1} given by Adeuayi *et al*. (2002) for soils of humid tropical region. The total Nitrogen of the experimental sites were 1.12 g kg^{-1} and 0.98 g kg^{-1}, lower than critical value of 1.50 g kg^{-1} by Ezeaku (2011) and Adeuayi *et al*. (2002). This low organic carbon and nitrogen shows that the soils are low in fertility. The low nitrogen could be attributed to high rate of mineralization due to excessive rain in the rain forest of south eastern Nigeria. The available phosphorus for 2018 was 18.50 mg kg^{-1} which was rated medium. That of 2019 was 24.00 mg kg^{-1} which was rated high based on the ratings of Chude *et al.* (2004) and Landon, 1991. The effective cation exchange capacities (ECEC) were 6.76 and 5.95 cmol kg^{-1} for 2018 and 2019 respectively. That of 2018 was rated medium while the one of 2019 was rated low by Enwezor *et al*. (1990). The exchangeable bases were equally low by Enwezor *et al.,* 1990 ratings. The high rainfall in the south eastern Nigeria leads to high rate of leaching of the exchangeable bases, this attributes to soil acidity. Therefore, organic amendments are needed to hold the exchangeable cations within the root zones of the soil.

Chemical Properties of the Manures used in the Study

The chemical compositions of the poultry manure and rice mill waste are presented in Table 2. From the analysis of the organic amendments used for the studies, poultry manure had higher levels of total nitrogen and potassium than the rice mill waste in the amendments used for 2018 and 2019 planting seasons, while phosphorus was higher in poultry manure in 2018 and higher in rice mill waste in 2019. A lower C: N ratio of 9.51 and 8.93 were obtained from poultry manure in 2018 and 2019, this showed faster rate of mineralization when compared with C: N ratios of 32.90 and 23.29 in rice mill waste (Iren *et al.,* 2014). The poultry manure and rice mill waste had high contents of potassium in 2018 and 2019 respectively. These are capable of improving the buffering potentials of the soil. Their high nitrogen content and organic matter showed the level of nutrient reserve in poultry manure and rice mill waste which will be released during mineralization. It equally indicates high moisture retentive capacity, soil aggregation and accommodation of different soil organisms which are agents of soil fertility (Nwosu, *et al*., 2013).

Properties of the Soil after Harvest for 2018 and 2019 Planting Seasons

Effects of sole and combined application of NPK (15:15:15), poultry manure and rice mill waste on soil chemical properties are presented in Table 3. Results in 2018, showed that the treatments significantly ($P < 0.05$) increased soil pH when compared to control. The experimental plot treated with 50% NPK + 50% poultry manure gave the highest pH of 5.3 which was significantly ($P < 0.05$) different from other treatments except plots treated with 100% poultry manure and 50% NPK + 25% poultry manure + 25% rice mill waste gave a pH of 5.2 each. The lowest was control plot with pH of 4.6. In 2019, the same trend was observed. This shows that plots amended with 100% rice mill waste recorded lower pH possibly due to the evolution of carbon dioxide during decomposition due to high C: N ratio (Table 2), which when reacted with soil water produces carbonic acid that reduced the pH of the soil. Low pH in the plots treated with NPK is also expected as mineral fertilizer releases its nutrient faster and it is prone to losses of nutrients through volatization and leaching. It is in agreement with Hoffman *et al*. (2001), who stated that if inorganic fertilizer, especially nitrogen carrier, when combined with manure, the manure reduces soil acidification and improves the nutrient buffering capacity and the release of nutrients.

Application of treatments significantly ($P < 0.05$) increased the organic carbon content of the soil more than the control in the two seasons except the plot treated with sole 100% NPK fertilizer in 2018 (Table 3). In 2018, application of 50% NPK + 25% poultry manure + 25% rice mill waste gave the highest organic carbon of 14.10 g kg^{-1}. There was no significant difference between plots treated with 50% NPK + 50% poultry manure (13.50 g kg^{-1}) and 50% NPK + 50% rice mill waste (12.50 g kg^{-1}) on organic carbon content. In 2019, plots treated with 50% NPK + 25% poultry manure + 25% rice mill waste gave the highest organic carbon of 16.90 g kg^{-1} and there was a significant ($P < 0.05$) difference between it and other treatments. These observations agreed with the findings of Akanbi *et al*. (2000) and Belay *et al*. (2001), who observed that application of organic wastes improved soil organic matter and increased moisture retention. The nitrogen content of the soils were significantly ($P < 0.05$) increased by application of the treatments when compared to control. In 2018, plots treated with 100% NPK gave the highest N content of 1.30 g kg^{-1}. It was significantly ($P < 0.05$) different from other treatments. It was followed by plots treated with 50% NPK + 50% poultry manure and 50% NPK + 25% poultry manure + 25% rice mill waste which gave N content of 1.10 g kg^{-1} each. In 2019, plots treated with 50% NPK + 50% poultry manure and 50% NPK + 25% poultry manure + 25% rice mill waste gave the highest N content of 1.30 g kg^{-1} each, which were significantly ($P < 0.05$) higher from other treatments. The results obtained from this research is in agreement with the findings of (Bello and Adekunle, 2013 and Ayeni, 2008) that combined use of inorganic fertilizer and organic manure will support the supply of adequate quantities of plant nutrient required to sustain maximum crop production.

Effects of sole and combined treatments of NPK, poultry manure and rice mill waste on soil available phosphorus is as shown in Table 3. The result shows that the treatments significantly ($P < 0.05$) increased soil available phosphorus when compared to control in both seasons. In 2018, among the treatments, plot treated with 50% NPK + 50% poultry manure recorded the highest value of available P of 23.50 mg kg^{-1}. This was followed by plot treated with 50% NPK+ 25% poultry manure + 25% rice mill waste (22.00 mg kg^{-1}) and then plot treated with 100% rice mill waste (21.00 mg kg^{-1}). The control plot was the least (12.20 mg kg^{-1}). In 2019, plot treated with 50% NPK+ 25% poultry manure + 25% rice mill waste recorded the highest value of available P (23.50mg kg^{-1}). There was no statistical difference among other treatments except plots treated with 100% rice mill waste, 50% NPK + 50% rice mill waste and control. Increase in the level of available P with application of these amendments could be as a result of an increase in soil pH and organic matter. Akanni *et al*. (2012) reported that there is positive correlation between soil organic matter and available P. Ravikumar and Krishnamoolthy (1983) disclosed that applying poultry manure boost the presence of phosphorus content of the soil.

The treatments significantly ($P < 0.05$) increased the effective cation exchange capacity (ECEC) of the soil in the two seasons. In 2018, the application of 50% NPK + 50% poultry manure had the highest ECEC of 7.40 cmol kg^{-1}. This was followed by plot treated with 100% poultry manure (7.23 cmol kg^{-1}) and then plot treated with 50% NPK + 25% poultry manure + 25% rice mill waste (7.10 cmol kg^{-1}). In 2019, plot treated with 50% NPK + 50% poultry manure had the highest ECEC of 7.02 cmol kg^{-1} which was closely followed by plot treated with 50% NPK + 25% poultry manure + 25% rice mill waste (6.99 cmol kg^{-1}). The higher records with treatments in combination with poultry manure was due to high organic matter in them since organic matter acts as a reservoir in storing basic cations and making them available for plant uptake (Ayeni *et al*., 2008). Equally in a study by Lal and Kang (1982), they observed higher ECEC with an increase in organic matter, and Lombin *et al*. (1991) equally reported that organic matter content of the soil is a major contributor to the ECEC of the soil. The same trend was observed under percentage base saturation. Plot treated with 50% NPK + 50% poultry manure recorded the highest base saturation of 96.76%, followed by plot treated with 50% NPK + 25% poultry manure + 25% rice mill waste (94.37%) and the least was the control plot (70.05%) in 2018. In 2019 result, plot treated with 50% NPK + 50% poultry manure recorded the highest base saturation of 90.88%. This was closely followed by plot treated with 50% NPK + 25% poultry manure + 25% rice mill waste (89.70). This increase in base saturation could be due to an increase in the organic matter content, exchangeable bases and rise in soil pH.

Effect of Mineral and Organic Manure on Nutrient Uptake of Ginger

The effects of sole and combined treatments of mineral and organic amendments on nutrient uptake are as shown in table 4. The application of treatments significantly ($P < 0.05$) increased nutrient uptake over the control plot with the combined application of 50% NPK + 50% poultry manure giving the highest in all the parameters determined for the two planting seasons. In 2018, the application of 50% NPK + 50% poultry manure gave the highest nitrogen uptake of 185.7 kg ha^{-1} and phosphorus uptake of 385.9 kg ha^{-1} which were significantly ($P < 0.05$) different from other treatments except the uptake of potassium 160.8 kg ha^{-1} was not significantly different from plots treated with 100% poultry manure (150.2 kg ha^{-1}) and 50% NPK + 25% poultry manure + 25% rice mill waste (148.9 kg ha^{-1}). In 2019, the trend was similar except in the uptake of potassium (158.7 kg ha^{-1}) which was only, not significantly ($P < 0.05$) different from sole treatment of 100% poultry manure (151.5 kg ha^{-1}). A scientific discovery carried out by Amanullah *et al.* (2007) pointed out that application of organic manure recorded great absorption of N, P and K than control. lyengar *et al.* (1984) equally disclosed great increase of phosphorus absorption in leaf sample of banana due to application of poultry manure.

Effect of Mineral and Organic Manure on Dry Matter Yield of Ginger

The effects of sole and combined treatments of mineral and organic amendments on dry matter yield are as shown in table 5. The application of treatments significantly ($P < 0.05$) increased the dry matter yield of ginger rhizome over the control with the application of 50% NPK + 50% poultry manure giving the highest dry matter yield in the two planting seasons. In 2018, the application of 50% NPK + 50% poultry manure gave the highest dry matter yield of 12 058.9 kg ha^{-1} which was significantly ($P < 0.05$) higher than other treatments. In 2019, plot treated with 100% Poultry manure gave the highest dry matter yield of 9 868.4 kg ha^{-1} which was not significantly different from plot treated with 50% NPK + 50% Poultry manure (9 702.3 kg ha^{-1}). The results obtained from this research is in agreement with the findings of (Bello and Adekunle, 2013; Ayeni, 2008 and Iren *et al*., 2012) that combined use of inorganic fertilizer and organic manure will support the supply of adequate quantities of plant nutrient required to sustain maximum crop production.

Conclusion

This study was carried out to find out the enhancement of mineral and organic fertilization on soil chemical properties, nutrient uptake and dry matter yield of ginger. Results from these studies have shown that combined use of 50% NPK 15:15:15 + 50% poultry manure significantly improved nutrient uptake and dry matter yield of ginger when compared to the sole treatments of 100% NPK 15:15:15 and 100% rice mill waste. The soil analysis after ginger harvest shows that 50% NPK 15:15:15 + 50% poultry manure significantly increased most of the soil chemical properties. Therefore, the experiment shows that the combined use of 50% NPK 15:15:15 + 50% poultry manure gave a better yield.

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Table 1: Physical and Chemical Properties of Soil before Experimentation

Soil Properties	Value	
	2018	**2019**
Sand (g kg^{-1})	814.00	850.00
Silt (g kg^{-1})	106.00	46.00
Clay (g kg^{-1})	80.00	104.00
Textural class	Loamy sand	Loamy sand
pH in (H_2O)	4.80	4.70
pH in (KCl)	3.90	3.90
Organic matter (g kg^{-1})	15.90	19.00
Organic carbon (g kg^{-1})	9.20	11.00
Total nitrogen (g kg^{-1})	1.12	0.98
C : N ratio	8.21	11.22
Available phosphorus (mg kg^{-1})	18.50	24.00
Exchangeable potassium (cmol kg^{-1})	0.08	0.10
Exchangeable calcium (cmol kg^{-1})	3.60	3.20
Exchangeable magnesium (cmol kg^{-1})	1.60	1.20
Exchangeable sodium (cmol kg^{-1})	0.24	0.17
Exchangeable acidity (EA) (cmol kg^{-1})	1.24	1.28
ECEC (cmol kg^{-1})	6.76	5.95
TEB (cmol kg^{-1})	5.52	4.67
Base saturation (BS) (%)	81.66	78.49

Table 2: Chemical properties of the manures used in the study

Parameter	2018		2019	
	Poultry manure (PM)	**Rice mill waste (RMW)**	**Poultry manure (PM)**	**Rice mill waste (RMW)**
Organic matter (%)	34.45	67.49	44.99	53.39
Organic carbon (%)	19.98	39.15	25.63	30.97
Total Nitrogen (%)	2.1	1.19	2.87	1.33
C:N ratio	9.51	32.90	8.93	23.29
Phosphorus (%)	4.55	3.20	2.58	3.53
Potassium (%)	2.90	1.97	1.66	1.07
Sodium (%)	4.90	2.45	2.30	1.03

Table 3: Effect of Sole and Combined Treatment of NPK, Poultry Manure and Rice Mill Waste on Soil Chemical Properties after G inger Harvest for 2018 and 2019 Planting Seasons

Treatment	pH		Total	Org.	Org.	Avail.	Exchangeable Bases				Exch.	ECEC	TEB	BS
	H_2O	KCl	N	C	Matter	P	Ca	Mg	Na	K	Acidity			(%)
				g kg^{-1}		(mg kg^{-1})				(cmol kg^{-1})				
2018 Experiment														
Control	4.60e	3.60c	0.60d	6.90d	11.9e	12.20d	2.00c	0.80e	0.19d	0.05c	1.30a	4.34d	3.04f	70.05e
100%NPK 15:15:15	4.80d	3.80b	1.30a	7.30d	12.6e	20.00bc	2.80b	1.20d	0.29a	0.06bc	0.80b	5.15c	4.35e	84.47d
100%Poultry Manure (PM)	5.20ab	4.10a	0.80c	10.40c	17.9d	19.00c	4.00a	2.40a	0.28a	0.07ab	0.48d	7.23a	6.75b	93.36bc
100%Rice Mill Waste (RMW)	5.00c	4.10a	1.00b	11.80bc	20.3c	21.00abc	3.20b	1.60c	0.25b	0.07ab	0.32f	5.44c	5.12d	94.12b
50%NPK + 50%PM	5.30a	4.10a	1.10b	13.50a	23.3ab	23.50a	4.40a	2.40a	0.28a	0.08a	0.24g	7.40a	7.16a	96.76a
50%NPK + 50%RMW	5.10bc	4.10a	1.00b	12.50ab	21.6bc	19.50bc	4.00a	2.00b	0.24b	0.08a	0.56c	6.88b	6.32c	91.86c
50%NPK+25%PM+25%RMW	5.20ab	4.10a	1.10b	14.10a	24.3a	22.00ab	4.00a	2.40a	0.22c	0.08a	0.40e	7.10ab	6.7b	94.37b
2019 Experiment														
Control	4.50c	3.50c	0.70c	6.20e	10.7e	14.80d	2.40e	0.80e	0.16e	0.05c	1.36a	4.77e	3.41f	71.49f
100%NPK 15:15:15	4.90b	3.60b	1.10b	8.10d	14.0d	23.30a	2.80d	1.20d	0.22c	0.06bc	0.88b	5.16d	4.28e	82.95e
100%Poultry Manure (PM)	5.20a	3.70a	1.00b	11.20c	19.3c	22.80ab	3.60b	1.60c	0.30a	0.07ab	0.7cd	6.29b	5.57b	88.55bc
100%Rice Mill Waste (RMW)	4.90b	3.60b	1.10b	11.90bc	20.5b	22.50b	3.20c	1.20d	0.25b	0.07ab	0.64d	5.36d	4.72d	88.06c
50%NPK + 50%PM	5.30a	3.70a	1.30a	11.90bc	20.5b	23.00ab	4.00a	2.00b	0.30a	0.08a	0.64d	7.02a	6.38a	90.88a
50%NPK + 50%RMW	5.00b	3.70a	1.10b	12.30b	21.2b	20.50c	3.20c	1.60c	0.29a	0.08a	0.80bc	5.97c	5.17c	86.60d
50%NPK+25%PM+25%RMW	5.20a	3.70a	1.30a	16.90a	29.1a	23.50a	3.60b	2.40a	0.20d	0.07ab	0.72cd	6.99a	6.27a	89.70ab

Note: Values with different letters in columns are significantly ($P < 0.05$) different according to DNMRT

Table 4: Effect of Organic and Mineral Fertilizers on Ginger Rhizome Nutrient Uptake

Treatment	2018			2019		
	N	P	K	N	P	K
	kg ha^{-1}			kg ha^{-1}		
Control	74.0e	107.4e	66.9d	70.1e	130.1e	70.0e
100% NPK 15:15:15	130.2d	315.5c	123.5c	110.2d	285.6b	107.8d
100% Poultry Manure (PM)	173.2b	337.3b	150.2ab	138.2b	284.2bc	151.5a
100% Rice Mill Waste (RMW)	127.2d	277.1d	119.0c	122.5c	209.1d	119.9c
50% NPK + 50% PM	185.7a	385.9a	160.8a	176.6a	334.7a	158.7a
50% NPK + 50% RMW	150.0c	340.7b	141.6b	122.9c	263.3c	122.5bc
50% NPK + 25% PM + 25% RMW	166.2b	345.4b	148.9ab	141.2b	302.6b	130.3b

Note: Values with different letters in columns are significantly ($P < 0.05$) different according to DNMRT

Table 5: Effect of Organic and Mineral Fertilizers on Ginger Dry Matter Yield

Treatment	2018	2019
	Dry Matter Yield (kg ha^{-1})	Dry Matter Yield (kg ha^{-1})
Control	5870.4d	5004.7d
100% NPK 15:15:15	8886.5c	7868.1c
100% Poultry Manure (PM)	11243.8b	9868.4a
100% Rice Mill Waste (RMW)	9084.5c	8750.9b
50% NPK + 50%PM	12058.9a	9702.3a
50% NPK + 50%RMW	10714.2b	7980.1c
50% NPK + 25%PM + 25%RMW	10792.9b	8405.8bc

Note: Values with different letters in columns are significantly ($P < 0.05$) different according to DNMRT