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Sole and combined effects of Mexican sunflower, cabbage residue, and poultry manure on soil chemical properties, growth, and yield of golden melon (*Cucumis melo* L.) in a derived savanna ecology of Nigeria

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ABSTRACT

Hitherto, the knowledge about the effect of mexican sunflower, cabbage residue, and poultry manure residues in the soil chemical conditions is still limited. Hence, a field experiment was carried out in 2020 to assess the effects of sole and combined applications of mexican sunflower (*Tithonia diversifolia)* leaves, cabbage (*Brassica oleracea*) residue and poultry manure on soil chemical properties and the performance of golden melon (*Cucumis melo* L.). The organic manures were applied at the rate of 120 kg N ha^{-1}. The treatments were: *Tithonia* leaves alone (1.42 kg/plot), cabbage residue applied alone (1.80 kg/plot), poultry manure applied alone (PM) (1.68 kg/plot), PM at 0.84 kg $plot^{-1}$ + *Tithonia* leaves at 0.71 kg $plot^{-1}$, PM at 0.84 kg $plot^{-1}$ + cabbage residue at 0.90 kg $plot^{-1}$, *Tithonia* leaves at 0.71 kg $plot^{-1}$ + cabbage residue at 0.90 kg $plot^{1}$, control. The seven treatments were laid out in RCBD with three replications. Organic manures (sole or combined) significantly increased the soil organic matter, N, P, K, Ca, Mg and performance of golden melon as compared with the control. When considered sole, PM increased soil chemical properties, growth and yield of golden melon relative to other manures. When combined, PM + cabbage has the highest value of these parameters. The increased performance of golden melon under PM + cabbage was due to improved soil chemical properties and also due to the fact that slowly decaying cabbage residue may allow the retention of released nutrients from rapidly decomposing PM within the rooting zone, thereby fostering greater efficiency of nutrient release and uptake. Consequently, locally available organic material can be used in improving soil and crop productivity, especially when they are combined.

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1.0 Introduction

During the last decades, the demand for organically grown products has increased because many people are concerned about the environment and believe that organic products are healthier than conventional ones (Riahi et al. 2009). This quest for organic fruit production has brought about the use of many types of organic / crop residues for soil fertility maintenance. Organic amendments can be a cheap and readily available source of organic matter for sustaining both the physical and chemical soil characteristics and crop yield. Poultry manure (PM), according to Wells (2002), is the digestive by-products of the feed ingested by poultry birds and associated bedding materials, wasted feeds, feathers, soil (picked up during recovery), and water used in the poultry production operation. The application of PM to soils can increase concentrations of carbon, Ca, K, Mg, N, and P in surface and subsurface soils (Adekiya et al., 2016). It also improves the physical characteristics of the soil (Adekiya *et al*., 2016).

Mexican sunflower (*Tithonia diversifolia*) is a shrub that belongs to the family Asteraceae. The shrub according to Sonke (1997), is everywhere in humid and sub-humid tropics. It was reported that it has high decomposition rate and a high concentration of N, P, and K (Adekiya, 2019; Jama et al., 2000; Gachengo et al., 1999).

Cabbage (*Brassica oleracea*) is a leafy vegetable of the Brassica family, which produces a significantly large amount of biomass consisting of leaves. However, a huge amount of waste (leaves, roots and stems) is generated during the harvesting and handling of cabbage (Naik et al., 2014). Leaves of cabbage are discarded and treated as wastes after harvest, which might be rich in nutrients Hitherto, the knowledge about the effect of these residues on soil chemical properties and crop yield is still limited (Pinto et al., 2012). For instance, a cabbage crop can leave approximately 60 tons ha^{-1} of fresh residues after harvest, containing around 180 kg N ha^{-1} of total nitrogen (Rahn et al., 1992). Similarly, Mexican sunflower is a rich source of essential nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium, which support plant growth, enhance soil microbial biomass, and reduce phosphorus sorption (Jama et al., 2000; Olabode et al., 2007). The application of 0.5 tons ha^{-1} of Mexican sunflower leaves to garlic has been shown to improve soil fertility, enhance plant growth and yield, and ultimately boost farmers' income (Pierre et al., 2019).

Poultry manure (PM) also serves as an excellent nutrient source for both subsistence and commercial crop producers. Its application lowers input costs, thereby increasing profitability (Ayoola and Makinde, 2008), while also improving soil fertility and crop yields (Adekiya et al., 2016). In addition, the quality of an applied organic amendment to the soil is determined by the type and the chemical compositions of the amendment among other things (Adekiya, 2018). No single soil amendment typically provides all the necessary nutrients in sufficient quantities. Therefore, combining multiple amendments may be necessary to achieve a balanced nutrient supply for optimal soil fertility and plant growth (Adekiya, 2019).

Pinto et al (2012) evaluated the effect of different organic compounds and bio-fertilizers on melon cropping with the combination of Napier grass, coconut bagasse, castor bean cake, goat manure, potassium super-phosphate, and thermo-phosphate as treatments. The highest commercial fruit yields of 27.13, 26.58 and 26.45 t ha^{-1} were obtained, respectively, by 77% coconut bagasse + 20% goat manure + 3% thermo-phosphate (a type of phosphorus fertilizer produced through the thermal processing of phosphate rock, often with the addition of other materials such as silicates or carbonates), by 50% Napier grass + 40% goat manure + 10% castor bean cake and by 50% Napier grass + 40% goat manure + 10% castor bean cake, at 10 L m^{-1} combinations (Pinto et al., 2012). As response of crop to an applied amendment varied with soil type and ecology, there is the need to experiment on amendment /combinations of amendments that will optimized soil and crop productivity in the derived savanna ecological zone of Nigeria. Therefore, the objectives of this study were to determine the sole and combined effects of *Tithonia diversifolia*, cabbage residue, and poultry manure on soil chemical properties, growth and yield of golden melon in a derived savanna ecology of Nigeria.

2.0. Materials and Methods

2.1. Site description and treatments

Two field experiments were conducted concurrently (site A and B) at the Teaching and Research Farm, Landmark University, Omu-Aran, Kwara State, Nigeria during the cropping season of 2020. Experiment at site B was conducted simultaneously as A so as to confirm the results of experiment A. Landmark University lies between lat 8° 9′N and long 5° 61′E at an altitude of 560 m and is located in the derived savanna ecological zone of Nigeria. The rainfall pattern is bimodal with peaks in June and October. The total annual rainfall in the area is about 1300 mm while the mean annual temperature is 32 °C. The soil at the sites of the experiment is an Alfisol classified as Oxic Haplustalf or Luvisol (FAO, 1998). At both sites A and B, the treatments consisted of: (1) *Tithonia* leaves applied alone (2.52 kg/plot), (2) cabbage residue applied alone (3.19 kg/plot), (3) poultry manure applied alone (PM) (2.27 kg/plot), (4) PM applied at 1.14 kg $plot^{-1}$ + *Tithonia* leaves applied at 1.26 kg $plot^{-1}$, (5) PM applied at 1.14 kg $plot^{-1}$ + cabbage residue applied at 1.60 kg $plot^{-1}$, (6) *Tithonia* leaves applied at 1.26 kg $plot^{-1}$ + cabbage residue applied at 1.60 kg $plot^{1}$, (7) control. All the organic manures were applied at the rate of 120 kg N ha^{-1}. This was equivalent to 3797 kg ha^{-1} of PM, 4195 kg ha^{-1} *Tithonia* leaves and 5309 kg ha^{-1} cabbage residue. The seven treatments were arranged in a randomized complete block design with three replications. Each block comprised of 7 plots and each plot was 3 × 2 m. Blocks were 1 m apart and plots were 0.5 m apart.

2.2. Land preparation, incorporation of manures, and sowing of golden melon seeds.

The experimental field was cleared manually using cutlass and thrashed removed from the site before mechanical (ploughing and harrowing) land preparation after which plots were marked out to the required plot size of 3 × 2 m. Poultry manure was obtained from the poultry section of the Landmark University Teaching and Research Farm. Fresh top Mexican sunflower was collected from a nearby farm containing green tender stems and leaves. Cabbage residue was collected from the sequel to cabbage harvest in Landmark University screen house. The manures were weighed and thereafter incorporated into the soil to a depth of approximately 20 cm. The plots were allowed for 3 weeks for equilibration of amendments before sowing of golden melon seeds.

The sowing of golden melon seeds was done in late May 2020. Two seeds were sown per hole at inter-row spacing of 0.5 m and 0.5 m intra-row spacing and later thinned to one to give a plant population of 40,000 plants ha^{-1}. Manual weeding was done starting from two weeks after planting and continued fortnightly using hoes while insect pests were controlled by spraying cypermethrin weekly at the rate of 30 ml per 10 L of water from 2 weeks and thereafter based on needs bases.

2.3. Determination of soil properties

In 2020, before the start of the experiment, soil samples from 0 – 0.15 m depth were randomly collected from 10 points from the experimental sites. The soil samples from each site were bulk together, air–dried, and sieved with 2 mm mesh sieve for analysis (to serve as composite soil sample). The hydrometer method was used for the determination of particle size (Gee and Or, 2002). Soil organic carbon (OC) was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Organic matter (OM) was calculated by multiplying organic carbon (OC) by a factor of 1.724. Total N was determined by the micro-Kjeldahl digestion method (Bremner, 1996). Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al., 1998). Exchangeable K, Ca, and Mg were extracted using 1 M ammonium acetate (Hendershot et al., 2007). Thereafter, concentration of K was determined on a flame photometer (JENWAY, PFP7), and Ca and Mg were determined by EDTA titration method. Soil pH was determined using a soil-water medium at a ratio of 1:2 with a digital electronic pH meter (PORTABLE pH/ EC/TDS/ TEMPERATURE METER, H19813-61). At the end of each year's experiment, soil samples were also collected on plot basis (with three samples from each plot and later bulked together) and similarly analyzed for soil chemical properties as described above.

2.4. Determination of Growth and yield of golden melon

Five golden melon plants were randomly selected per plot for the determination of growth parameters (vine length and the number of leaves per plant) at the mid flowering stage of the golden melon plant (about 45 days after sowing). Vine length was determined by measuring with a meter rule from the base to the shoot buds and the number of leaves was by manual counting. Golden melon fruits were harvested counted and weighed at harvest (about 75 days after sowing).

2.5. Statistical analysis

Data collected from each treatment were subjected to analysis of variance (ANOVA) test using SPSS 21.0, and treatment means were separated using Tukey's HSD test (honestly significantly different test) with p = 0.05. Results and Discussion

3.0. Result and Discussion

3.1. Soil and manure properties

Tables 1 and 2, respectively, show the results of the physical and chemical properties of the soil prior to experimentation and analysis of manures (PM, cabbage residue and *Thithonia* leaves) used for the experiment. The soils of the two sites were sandy loamy, acidic, and low in OM, N, P, K and Mg but moderate in Ca according to the critical level of 3.0% OM, 0.20% N, 10.0 mg kg^{-1}available P, 0.16–0.20 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca, and 0.40 cmol kg^{-1} exchangeable Mg recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000). Results also showed that PM has the highest values of N, P, Ca and Mg and lowest in OC and C: N ratio, whereas, *Tithonia* has the highest value of K. Cabbage has the highest OC and C: N ratio values.

3.2. Effect of sole and combined application of manures on soil chemical properties

Table 3 shows the results of the effect of sole and combined application of manures on soil chemical properties. All manures (PM, *Tithonia* and cabbage residue) both sole and combined applications increased soil chemical properties (SOM, N, P, K, Ca and Mg) compared with the control. Among the sole applications from both sites, cabbage residue resulted in the highest SOM which was significantly (P= 0.05) different from PM and *Tithonia* leaves. Whereas PM had significantly higher values of N, P, Ca and Mg. *Tithonia* leaves had values of N, Ca and Mg among sole applications. The values of P were not significant between *Tithonia* and cabbage residue. Among the combined applications in both sites, PM + cabbage significantly (P = 0.05) resulted in higher values of SOM, N, P, K, Ca and Mg compared with PM+ *Tithonia* and *Tithonia* + cabbage by percentage increases of 1.91% and 2.82%, 28.94% and 25.64%, 30.28% and 13.09%, 16.66% and 3.27%, 9.06% and 6.09%, 19.58% and 16.0% for SOM, N, P, K, Ca and Mg, respectively using the average of the two sites. The values of K between PM + cabbage and *Tithonia* + cabbage was not significantly different. Among all the sole and combined manures together, the reducing order of SOM was cabbage = PM + cabbage = *Tithonia* + cabbage > *Tithonia* > PM + *Tithonia* > PM > control while that of N was PM + cabbage > PM = *Tithonia* + cabbage = PM + *Tithonia* > *Tithonia* > cabbage > control.

3.3. Effect of sole and combined application of manures on golden melon performance

Figure 1 shows the results of the effect of sole and combined application of manures on golden melon growth and yield. Sole and combined application of organic manure increased the growth and yield of golden melon compared with the control. Among sole manures in both sites, PM amendment led to the highest golden melon leaves, vine length, and average fruit weight compared with *Tithonia* and cabbage. There were no significant differences between PM, *Tithonia* and cabbage for golden melon's fruit number. Using the means of the two sites, PM increased the weight of golden melon by 14.6 and 44.6% compared with *Tithonia* and cabbage. Among combined treatments, PM + cabbage significantly (P = 0.05) increased growth and yield compared with PM + *Tithonia* and *Tithonia* + cabbage. There were no significant differences between the combined treatments for fruit numbers. Also, among all treatments (sole and combined) PM + *Tithonia* had the highest growth and yield values. Using the means from both sites, this

Table 1: Soil properties prior experimentation

Property	Site A	Site B
Sand (%)	68.1	68.2
Silt (%)	16.5	16.5
Clay (%)	15.4	15.3
pH (water)	5.72	5.72
Organic matter (%)	1.92	1.92
Total N (%)	0.14	0.14
Available P (mg kg^{-1})	8.8	8.7
Exchangeable K (cmol kg^{-1})	0.15	0.15
Exchangeable Ca (cmol kg^{-1})	2.41	2.39
Exchangeable Mg (cmol kg^{-1})	0.36	0.33

Table 2: Chemical properties of poultry manure (PM), *Tithonia* and cabbage residue used

	OC (%)	N (%)	C: N ratio	P (%)	K (%)	Ca (%)	Mg (%)
PM	21.8c	3.16a	7.6c	1.28a	1.68c	3.2a	0.63a
Tithonia	30.6b	2.86b	9.1b	0.40b	4.43a	3.1a	0.10c
Cabbage	40.1a	2.26c	15.1a	0.21c	3.08b	1.2b	0.30b

Values followed by similar letters under the same column are not significantly different at p = 0.05 according to Tukey's HSD test (honestly significantly different test).

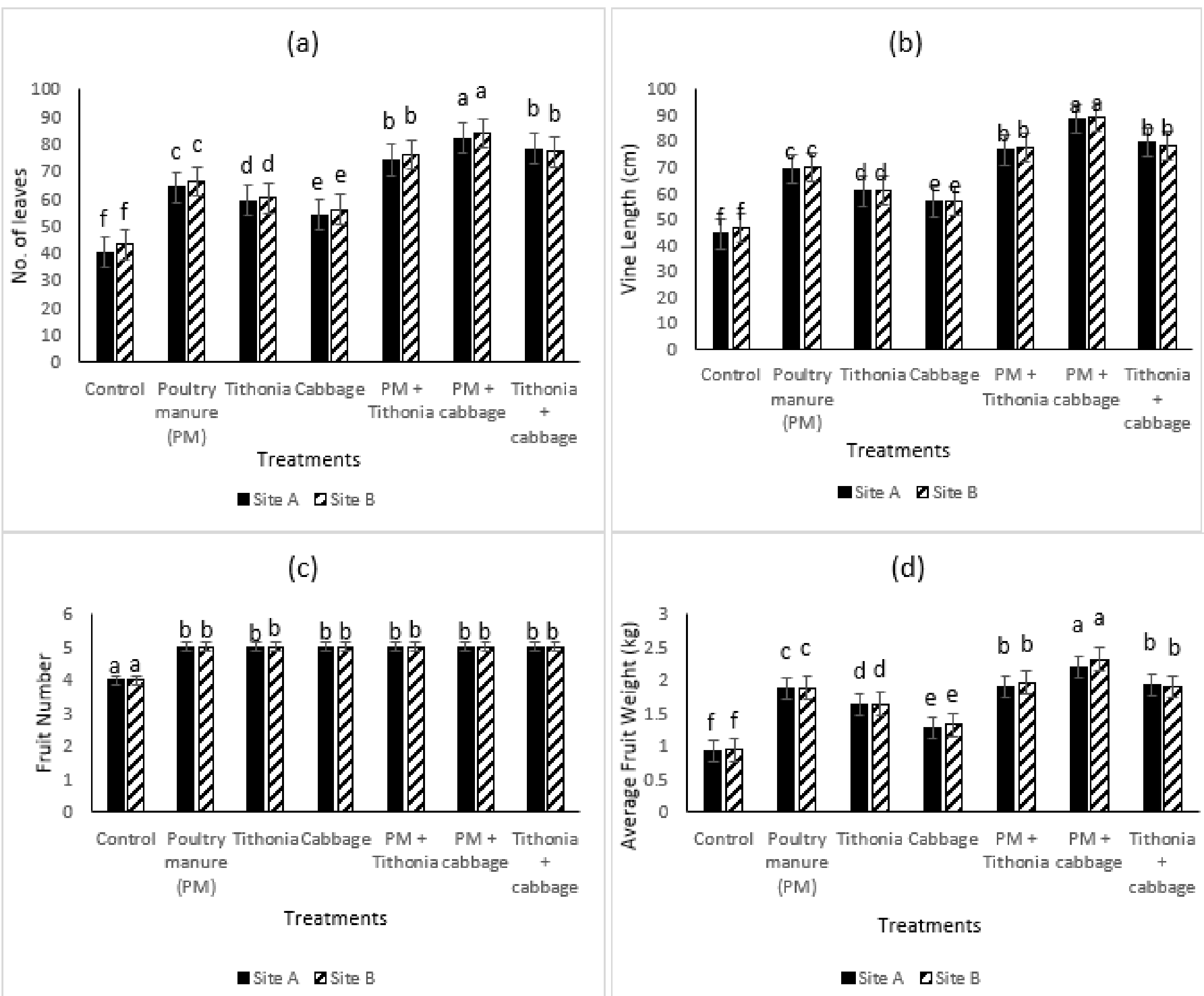

Figure 1: Growth and yield parameters of golden melon in response to sole and combined applications of organic manures. Vertical bars show standard errors of paired comparisons; bars marked with different letters show means significantly different at 5% level according to Tukey's HSD test (honestly significantly different test).

treatment increased the fruit weight of golden melon by 20.2, 38.6, 73.8, 17.1, 17.7 and 143.0 %, respectively, when compared with PM alone, *Tithonia* alone, cabbage alone, PM + *Tithonia*, *Tithonia* + cabbage and control.

Table 4: Correlation coefficient between growth and yield parameters of golden melon and soil chemical properties.

		SOM	N	P	K	Ca	Mg
Number of leaves	Site A	0.794*	0.926**	0.967**	0.805*	0.949**	0.870*
	Site B	0.701*	0.909**	0.967**	0.798*	0.950**	0.911**
Vine length	Site A	0.763*	0.958**	0.970**	0.770*	0.945**	0.896**
	Site B	0.757*	0.934**	0.968**	0.749	0.943**	0.924**
Fruit number	Site A	0.777*	0.641	0.708	0.900**	0.537	0.808*
	Site B	0.814*	0.702	0.707	0.895**	0.526	0.790*
Fruit weight	Site A	0.706*	0.936**	0.932**	0.782*	0.843*	0.908**
	Site B	0.748*	0.971**	0.940**	0.786*	0.849*	0.930**

* Significant difference at p = 0.05. ** Significant difference at p = 0.01

3.0. Discussion

The low nutrient contents of the site before experimentation can be as a result of continuous cultivation of the soil over the years without soil amendment (Adekiya, 2019). Salako (2003) earlier reported that Nigeria savanna's soils are low in organic matter and chemical fertility. Sole manures or their combinations increased OM, N, P, K, Ca, and Mg compared with the control (Table 3). PM, *Tithonia* and cabbage residue contain nutrients (Table 2) and these nutrients are released into the soil when they decomposed.

Before now, PM had been found to be a natural and effective source of nutrients (Adekiya et al., 2016; Agbede and Ojeniyi, 2009; Odedina et al., 2011) and its presence also increases cation exchange capacity of soil. It also has liming effect (Odedina et al., 2011). Although use of cabbage residue as manure is very scarce, Anunciação et al. (2011) reported that cabbage leaves contain 2.88% K, 1.77% Na, 1.44% Ca and 0.49% P. Shokalu et al. (2010) found that *Tithonia* significantly improved pH, N, P, K, Mg, and Zn contents of the soil. The higher soil nutrient concentration of PM when applied alone relative to cabbage and *Tithonia* could be due to the fact that (1) poultry manure is inherently rich in essential nutrients (Table 2) and it contains higher concentrations of these macronutrients (N, P, Ca and Mg) compared to the residues of cabbage or *Tithonia* leaves. (2) Poultry manure decomposes quickly, (C: N ratio of 7.6) releasing nutrients into the soil in a form that plants can readily absorb. This rapid nutrient availability contrasts with the slower decomposition rates of cabbage residue (C: N ratio of 15.1) and *Tithonia* leaves (C: N ratio of 9.1), which may not release their nutrients as quickly or in as concentrated a form. (3) The application of poultry manure might stimulate microbial activity (Joseph et al., 2016) more effectively than cabbage or *Tithonia*. The microorganisms break down organic matter and convert nutrients into bioavailable forms. This enhanced microbial activity leads to better nutrient cycling and retention in the soil.

The higher nutrient concentrations of PM + cabbage compared with other treatments (sole or combined) was due to the contrasting C: N ratio of PM (low) and cabbage (high) in this context, therefore, when cabbage was combined with PM with low C: N ratio, there was better / faster mineralization and nutrient release compared with their sole forms, PM + *Tithonia*, or *Tithonia* + cabbage with lesser quality.

The improved growth and yield of golden melon with PM, cabbage, *Tithonia*, and their combinations in this experiment compared with the control was as a result of improved soil chemical properties (OM, N, P, K, Ca and Mg) of the soil as a result of the incorporated manures. The positive and significant correlation among growth and yield characteristics of golden melon and SOM, N, P, K, Ca and Mg contents of the soil (Table 4) showed that soil chemical properties influenced the growth and yield of golden melon in this experiment. The improved growth and yield of golden melon could also be as a result of improved soil physical properties as a result of the applied manure which would have enhanced better root growth and better water and nutrient uptake and therefore better growth and yield. Application of manures to soil have been reported (Adekiya et al., 2019) to in addition to improving soil chemical properties also improve soil physical properties as for this case.

Among sole treatments of PM, cabbage and *Tithonia*, PM had the highest values of growth and yield of golden melon. This was because of its improved soil chemical properties compared with others (cabbage and *Tithonia*). That means the uptake of nutrient elements increased proportionally with the availability of the nutrient elements in the soil. There was significant correlation between soil chemical properties and golden melon yield for sole applications of PM, *Tithonia* leaves and cabbage residue. The R values were -0.999, 0.965, 0.997, -0.635, 0.679 and 0.667, respectively for SOM, N, P, K, Ca and Mg at P = 0.05.

Also, among all treatments, PM + cabbage had the highest value of golden melon yield. This was due to improved soil physical conditions and optimum availability of soil nutrient under this treatment. In addition to improving soil physical properties, the humus of slowly decaying cabbage (with high C: N ratio) may also allow retention of released nutrient from rapidly decomposing PM (with low C: N ratio) within the rooting zone, thereby fostering greater efficiency of nutrient uptake and increase in yield. Greater synchronisation of nutrient supply with crop demand is considered one of the challenges facing organic resource management (Myers et al., 1994; Palm et al., 1997) and the observed differences in decomposition rate between PM + cabbage residue may present an opportunity in that regard. Higher N mineralization occurs where two organic amendments were combined, compared to their sole forms, indicating a synergistic relationship between the inputs (Palm et al., 2001; Singh et al., 2007).

4.0. Conclusion

Organic manures (sole or combined) significantly increased the soil organic matter, N, P, K, Ca, Mg and performance of golden melon as compared with the control. When considered sole, PM increased soil chemical properties, growth and yield of golden melon relative to other manures. When combined, PM + cabbage had the highest value of soil chemical properties (soil organic matter, N, P, K, Ca and Mg), growth and yield of golden melon. This treatment increased the fruit weight of golden melon by 20.2, 38.6, 73.8, 17.1, 17.7 and 143.0 %, respectively, when compared with PM alone, *Tithonia* alone, cabbage alone, PM + *Tithonia*, *Tithonia* + cabbage and control. The increased performance of golden melon under PM + cabbage was due to improved soil chemical properties and also due to the fact that slowly decaying cabbage residue may allow retention of released nutrients from rapidly decomposing PM within the rooting zone, thereby fostering greater efficiency of nutrient release and uptake. Consequently, locally available organic material can be used in improving soil and crop productivity especially when they are combined

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