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RESEARCH PAPER

Impact of sole and integrated use of plant residues as soil amendments on tomato (*Lycopersicum esculentum* Mill.) production

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Key Message: This research evaluates tomato production using plant residues in sole/integrated form with inorganic NPK. Kolanut pod (5 t ha^{-1}) produced higher yield than NPK. Cocoa pod and kolanut/cocoa pod integration with NPK produced yield achievable under NPK without nutritional quality reduction.

Abstract: Poor soil condition is a major problem of tomato production in Nigeria. Soil amendment with plant-based materials is an integral part of organic agriculture; hence an experiment was conducted on sole and integrated use of plant residues as soil amendments in tomato cultivation and production. Treatments include: TR0 (No soil amendment as the control), TR1(100% kolanut pod husk), TR2(100% coconut pod husk), TR3 (100% cocoa pod husk), TR4(100% NPK),TR5(75% kolanut pod husk + 25% NPK), TR6(75% coconut pod husk + 25% NPK), TR7(75% cocoa pod husk + 25% NPK), TR8(50% kolanut pod husk + 50% NPK),TR9(50% coconut pod husk + 50% NPK), TR10(50% cocoa pod husk + 50% NPK),TR11(25% kolanut pod husk + 75% NPK), TR12(25% coconut pod husk + 75% NPK) and TR13(25% cocoa pod husk + 75% NPK). Soil amendments improved plant height, number of leaves and branches, leaf area, root length, number of roots and relative growth rate over the control except stem girth without noticeable difference (7.46 cm in the control and 6.35-8.66 cm under soil amendments). Among soil amendment treatments, growth and biomass were best under TR1 with variations in statistical differences from others. Soil amendment reduced root/shoot ratio (0.54 in the control against 0.15-0.29 under soil amendments). There was an increase in leaf total chlorophyll significantly at TR1-TR4 (0.83-0.85 mg/g fresh weight) but at a non-significant level at TR5-TR13 (0.39-0.54 mg/g) compared to the control (0.34 mg/g). The amended soil led to a significant yield improvement with the highest fruit yield/plant at TR1 (18.82 g) without statistical differences at 95% probability level from TR3-TR5 (16.19 - 14.52 g) and TR7 (14.33 g) but significantly higher than TR2 (14.12 g) and TR8-TR13 (5.32-11.08 g). The results obtained from the fruit yield showed an improved fruit size of 10.75 cm in the control but was lesser in the the soil amended with values ranging from 28.83 to 55.35 cm. Soil amendments improved fruit nutritional and proximate compositions of the tomato.

Keywords: Integrated fertilizer, Plant materials, Soil fertility, Tomato production

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Introduction

Tomato (*Lycopersicum esculentum*) is a member of Solanaceae family. It is a vegetable crop grown worldwide and ranks third globally in vegetable production (Sadaf et al., 2012). Its global production during 2011 was over 159 million metric tonnes (Ministry of Food, Agriculture and Livestock [MINFAL], 2011). This figure dropped to 27.3 metric tonnes according to the Global Tomato Industry Report in 2018, while production in 2019 was estimated at 37.5 million metric tonnes (Colvine & Branthome, 2019). Over 80% of tomatoes grown throughout the world are processed into a variety of products for consumption (Viskelis et al., 2015). Vegetables and fruits are sources of over 90% vitamin C in the diet of human beings, and the most important is tomato (Vallejo et al., 2002). Several studies have proved the value of tomato and its products in reducing various ailments because they contain high amounts of antioxidants such as carotenoids, polyphenols, ascorbic acid etc. (Guichard et al., 2001; Toor et al., 2005; Olaniyi & Ajibola, 2008; Perveen et al., 2015; Ye et al., 2020). Lycopene is the most abundant carotene in the tomato fruit; it constitutes about 90% of the total carotenoids in the fruit (Viskelis et al., 2015). According to Perveen et al. (2015), lycopene is the most important antioxidant with a high oxygen free radical-scavenging and quenching capacity, and thus provides protection against chronic diseases such as several types of cancer, including cancer in the mouth, pharynx, esophagus, stomach and large intestine, as well as cardiovascular diseases.

In Nigeria, there is a shortfall in tomato production because the yields across the country have remained low. It was reported by the Horticultural Institute of Nigeria in 2017 that tomato national production stands at 2.3 metric tonnes as against 3 million metric tonnes national demand. Low soil fertility coupled with continuous cropping without nutrient replenishment measures is one of the major limitations to tomato production in the tropics, and this has in recent times brought about serious concerns to many small scale African farmers (Kimani et al., 2003). Several reports have indicated that crop yield can be improved by applying inorganic fertilizers to soil. Ciceri and Allanore (2019) specified that fertilizer usage can lead to an increase in crop yield in Sub-Saharan Africa of about 30%–50% in the next 30 years. While there is an increased advocacy for the use of inorganic fertilizers, there are limitations because they are most often not readily available, expensive, associated with nutrient imbalance and soil acidification. Maintenance of soil fertility with inorganic fertilizer involves repeated application at every planting season because the synthetic N, P and K in the fertilizer can rapidly evaporate to the atmosphere or leach and drain away with water (Aisha et al., 2007). Environmental pollution has also been found to be associated with it (Okwu and Ukanwa, 2007) as their repeated and excessive use is associated with soil, water and air pollution (Diacono & Montemurro, 2010; Savci, 2012; Komakech et al., 2015).

Chemical fertilizers also create numerous harmful effects to animals and human health through the food chain by consuming the plant products. Research has revealed reduction in crop nutritional quality with chemical fertilizer application (Marzouk & Kassem, 2011). As such, during the last decades, the demand for organically grown tomato products has increased because many people are concerned about the environment and believe that organic products are healthier than the conventional ones (Riahi et al., 2009). This has called for adopting other methods in replenishing soil nutrients for yield improvement either by organic fertilizer or reduced concentration of inorganic fertilizer with mixture of locally available sources of organic materials to ensure optimization of fertilizer use (Kaizzi et al., 2017).

Organic fertilizers have been reported to have the potential to function as alternative sources of soil nutrient enrichment to mineral fertilizers (Naeem et al., 2006). Many studies have shown that organic materials can produce higher yield or yield achievable under inorganic fertilization while organically produced tomato fruits contain higher amounts of antioxidants, total phenolics and ascorbic acid (Toor et al., 2006), and more total soluble solids compared to chemically grown ones (Rickman-Pieper & Barrett, 2008). The use of locally available organic sources from plants and animals for improvement of soil fertility and enhancing productivity capacity of degraded or nutrient-deficient soil have gained popularity in many nations of the world (Huang et al., 2004; Tejada & Benitez, 2014). However, most research in this area has focused largely on animal wastes with limited attention on plant residues. Of course, soil amendment with plant residues can help to enhance soil organic carbon, physical properties, biological activities and nutrient availability (Abbasi et al., 2015). Incorporating plant-based nutrient sources into soil provides a source of energy for microorganisms that will act on the organic materials to ensure availability of essential nutrients for plant growth through the soil process of mineralization and immobilization (Abbasi et al., 2015). They observed that the leaves, stems and roots of soybean, maize etc. incorporated into soil provided a means of nutrient recycling of C and N in the plant-soil system (Abbasi et al., 2015).

Sole application of organic nutrient sources may not be sufficient to overcome the challenge of low soil fertility; crop nutrient requirements can be met if small quantities of inorganic fertilizers are integrated to plant materials as a strategy to achieve nutrient balance in soil. This can reduce leaching of nutrients that can bring about contamination of groundwater especially in poor sandy soil (Manna et al., 2000). This will help in taking full advantage of readily available organic resources like plant residues to minimize over-reliance on chemical fertilizers (Ghosh et al., 2004). Fortunately, there is an abundance of unutilized coconut, cocoa and kolanut pod husks produced and discarded by farmers in Nigeria, which we hypothesized that they can be recycled for tomato production as an alternative. The objective of this study was therefore to evaluate the effects of sole and integrated use of plant residues as soil amendments in tomato production.

Materials and Methods

Location of experiment

This research was conducted at the screen house of the Department of Plant Science & Biotechnology (PSB), Adekunle Ajasin University, Akungba-Akoko (AAUA), Ondo State, Nigeria ((latitude 7.2 ^{0}N, longitude 5.44 ^{0}E).

Planting materials

Viable tomato seeds authenticated by the National Horticultural Research Institute (NIHORT) were obtained from the Premier Seed Nigeria limited, Ibadan, Nigeria. The top soil collected from the experimental plot of PSB Department, AAUA was used for planting. It was a sandy-loam soil with known physicochemical properties (Kekere et al., 2019). Inorganic fertilizer was purchased from an Agrochemical Store at Akure, Ondo State, Nigeria. Agricultural wastes used as organic fertilizer were collected from Arix Global Farms Ltd and OJ Ija's Farm at Akure, Ondo State, Nigeria.

Preparation of soil amendments

The organic fertilizers used were kolanut pod husk (KPH), coconut pod husk (CoPH) and cocoa pod husk (CPH). The plant materials were dried and ground to fine powder to enhance mineralization within the experimental period. Pellets of NPK 15:15:15 fertilizer was used as the inorganic fertilizer. The organic fertilizer application rate was 5 t ha^{-1} (Tanimu et al., 2013; Adeniyan, 2014) while the inorganic NPK application rate was as recommended for tomato at 50 kg ha^{-1}. The organic/inorganic fertilizer mixtures (TR5-TR13) were prepared by measuring the quantity corresponding to the percentage of the sole application rate. The descriptions of the treatments are shown in Table 1.

Table 1 Treatments used for the experiment

Treatment code	Treatment description
TR0	Control (No soil amendment)
TR1	100% kolanut pod husk
TR2	100% coconut pod husk
TR3	100% cocoa pod husk
TR4	100% NPK 15:15:15
TR5	75% kolanut pod husk: 25% NPK
TR6	75% coconut pod husk: 25% NPK
TR7	75% cocoa pod husk: 25% NPK
TR8	50% kolanut pod husk: 50% NPK
TR9	50% coconut pod husk: 50% NPK
TR10	50% cocoa pod husk: 50% NPK
TR11	25% kolanut pod husk: 75% NPK
TR12	25% coconut pod husk: 75% NPK
TR13	25% cocoa pod husk: 75% NPK

Experimental set-up

Ten (10) tomato seeds were planted in 3 kg topsoil filled into poly-ethylene pots perforated at the bottom to ensure drainage. After germination, potted seedlings were thinned to one in each pot at 3 weeks after planting. Treatment application commenced at 1 week after thinning (4 weeks after sowing) through incorporation of soil amendment into the soil. Treatments were also applied at 7 weeks after planting based on the fact that tomato requires fertilizer application twice in a growing season for optimal performance; one at the early vegetative stage and the other at the beginning of reproductive stage (Olaniyi & Ajibola, 2008). Each pot contained a single plant with completely randomized design with each treatment having 6 replicates. The experiment lasted for 12 weeks.

Measurement of growth parameters

Metre rule was used to measure plant height from the shoot base to the apical bud, and a digital Vernier caliper (model 0-200 mm) was used to measure stem girth at 5 cm point from the soil surface. Leaves were manually counted and leaf area determined by modified method of Eze (1965) method. The plant relative rate of growth was calculated with: In mass2-In mass1/ Time. Mass1= initial biomass before treatment, mass 2 = final biomass biomass when the experiment was terminated and, time= the period (days) between commencement of treatment and termination of the experiment.

Measurement of fresh and dry mass

Plants were carefully uprooted at the end of the experiment after soil moistening to avoid loss of roots. Each plant was separated into leaves, stems, roots and fruits. Plant parts were weighed fresh and after drying with Metler PC 180 weighing balance.

Determination of leaf total chlorophyll

Leaf total chlorophyll was measured with a method described by Arnon (1949). It was calculated by the following formula: Total chlorophyll= $[(20.2 \times D645) + (8.02 \times D665)] \times [50/1000] \times [100/5] \times ½$, where D645= absorbance of the extract at 645 wave length (nm), 663 = absorbance of the extract at 663 wave length (nm).

Yield measurement

The numbers of fruits harvested from each plant throughout the period of the experiment were cumulated as the number of fruits produced per plant. The diameter of each fresh fruit was also measured. The fruits were weighed fresh during each harvest and summed up at the end. Fresh fruits were oven-dried to a constant weight at each harvest and weighed.

Plant nutritional and proximate analyses

Dried fruit samples were ground to powder form using a Philip model blender. This was digested using 10 ml of 20% sulphuric acid. Sodium and potassium were analyzed by flame photometry while magnesium and calcium were determined by Ethylene diamine tetraacetic acid (EDTA) titration according to (Association of Official Analytical Chemists [AOAC], (1990). The proximate composition was also assayed using the standard laboratory procedures by AOAC (1990).

Statistical analysis

Data were analysed with One-way ANOVA and mean separation with Tukey HSD test at 95% probability through SPSS statistical package, version 24.0.

Results

Effect of plant residues on growth parameters

Soil amendment with sole organic/inorganic fertilizers as well as their integration increased growth of tomato over those without soil amendment except stem girth where there was no significant difference (Table 2). Among the soil amendment treatments, the highest plant height was recorded at TR1 (sole coconut pod husk), although it did not differ significantly from other soil amendment treatments. Number of leaves was also highest at TR1 but with significant difference from other treatments; followed by TR3-TR5 which in turn did not significantly differ among one another as well as TR6-TR7 and TR9-TR13. In the case of the number of branches, soil amendments did increase it but insignificantly compared to the control. Results obtained for stem girth and root length followed the same trend with that of number of branches. In addition, leaf area increased at a significant level when soil was amended compared to when there was no soil amendment.

There was however no significant difference among soil amendment treatments. The number of roots produced by plants grown without soil amendment did not differ significantly from those grown in soil with sole coconut pod husk or its mixture with NPK fertilizer (TR2, TR6, TR9 and TR13), while all other soil amendment treatments significantly increased number of roots. Furthermore, the relative growth rate value was significantly higher in plants exposed to soil amendment than the control; but growth rate was highest in plants treated with 100% coconut pod husk when values under soil amendment treatments were compared. Statistics revealed that the control with the lowest relative growth rate did not significantly differ from TR3 and TR6-TR13 while TR3-TR5 had values that were higher significantly than the control treatment.

Effect of plant residues on fresh and dry mass

The below- and above-ground plant parts dry weights and total biomass of plants grown in soil amended with fertilizer were higher in values than in those grown without soil amendments (Table 3). Dry root weight of plants in amended soil did not differ significantly from the treatments except those treated with 100% coconut pod husk (TR1) where a significant increase was recorded. Soil amendment significantly increased shoot dry weight compared to the control with the highest value recorded at TR1 that did not differ significantly from TR3-TR5 and TR7-TR8 but significantly from other soil amendment treatments. Plants grown on amended soil had significantly higher biomass than those grown without soil amendment. TR1 produced plants with the highest biomass with statistical similarity to TR3-TR5 which differed significantly from TR9-TR13. In the case of root/shoot ratio, soil amendment reduced it significantly in comparison with the control; among the soil amendment treatments however, TR3-TR8were significantly lower than others.

Effect of plant residues on yield

The amended soil led to a significant yield improvement in tomato relative to the control (Table 4). In amended soils, fruits produced per plant were more at TR1 than others but at a non-significant level. Fruit yield per plant was best at TR1 with statistical similarity to TR3-TR5 and TR7 but significantly higher than TR2 and TR8-TR13. Fruit diameter was also best under TR1 which differed from TR9 only among soil amendment treatments.

Effect of plant residues on fruit nutritional and proximate compositions

Soil amendments improved fruit nutritional and proximate compositions of the tomato (Table 5). These involved N, P, K, Ca, Mg and Na as well as ash, crude fibre, crude protein, nitrogen-free extract (NFE) and lipid; with higher values under soil amendments than the control treatment. The leaf total chlorophyll value that was 0.34 mg/g under the control was significantly lower than in plants subjected to soil amendment treatments at TR1-TR4 (0.84-0.85 mg/g) without significant difference from TR5-TR13 (0.39-0.54 mg/g) (Fig. 1).

Table 2 Effect of sole and integrated use of plant residues on growth parameters of tomato

Treatment	Growth parameters							
	PH (cm)	NoL	NoB	LA (cm^2)	SG (cm)	RL (cm)	NoR	RGR (g/g dry weight)
TR0	69.00^{ab}	77.17^{c}	11.83^{ab}	37.59^{c}	7.46^{a}	14.75^{ab}	23.15^{c}	0.044^{c}
TR1	100.65^{a}	159.17^{a}	18.83^{a}	83.81^{a}	8.66^{a}	23.50^{a}	45.43^{a}	0.080^{a}
TR2	77.66^{ab}	79.00^{c}	13.83^{ab}	55.99^{ab}	7.43^{a}	15.55^{ab}	28.14^{c}	0.048^{c}
TR3	89.50^{ab}	114.67^{b}	18.00^{a}	64.45^{ab}	7.68^{a}	21.08^{a}	36.45^{ab}	0.066^{ab}
TR4	95.66^{a}	112.67^{b}	18.17^{a}	69.36^{ab}	7.67^{a}	16.23^{ab}	38.64^{ab}	0.066^{ab}
TR5	90.16^{ab}	116.17^{b}	16.87^{a}	72.05^{a}	8.56^{a}	17.08^{ab}	39.12^{ab}	0.078^{a}
TR6	69.16^{ab}	79.33^{c}	11.50^{ab}	56.96^{ab}	6.67^{a}	15.66^{ab}	27.46^{c}	0.053^{c}
TR7	73.16^{ab}	80.17^{c}	14.50^{ab}	69.67^{a}	6.35^{a}	17.25^{ab}	34.01^{ab}	0.053^{c}
TR8	86.78^{ab}	116.17^{b}	15.90^{ab}	70.61^{a}	7.17^{a}	16.00^{ab}	30.57^{ab}	0.055^{c}
TR9	83.66^{ab}	96.33^{c}	14.76^{ab}	54.08^{ab}	7.18^{a}	18.03^{ab}	27.11^{c}	0.054^{c}
TR10	75.16^{ab}	98.17^{c}	13.90^{ab}	67.80^{ab}	7.18^{a}	15.08^{ab}	40.38^{a}	0.057^{c}
TR11	70.83^{ab}	78.33^{c}	12.50^{ab}	57.80^{ab}	7.17^{a}	15.83^{ab}	38.41^{ab}	0.050^{c}
TR12	80.33^{ab}	81.50^{c}	12.83^{ab}	59.16^{ab}	6.98^{a}	14.88^{a}	25.31^{c}	0.049^{c}
TR13	85.66^{ab}	98.00^{c}	13.83^{ab}	73.58^{a}	7.37^{a}	18.79^{ab}	38.24^{ab}	0.050^{c}

PT = Plant height; NoL = Number of leaves; NoB = Number of branches; LA = Leaf area; SG = Stem girth; RT = Root length; NoR = Number of roots; RGR = Relative growth rate; Values are means of 6 replications; Means with the same letters in superscript on the same column are not significantly different at p=0.05 (Tukey HSD test); TR0 = control, TR1 = 100% kolanut pod husk, TR2 = 100% coconut pod husk, TR3 = 100% cocoa pod husk, TR4 = 100% NPK, TR5 = 75% kolanut pod husk + 25% NPK, TR6 = 75% coconut pod husk + 25% NPK, TR7 = 75% cocoa pod husk + 25% NPK, TR8 = 50% kolanut pod husk + 50% NPK, TR9 = 50% coconut pod husk + 50% NPK, TR10 = 50% cocoa pod husk + 50% NPK, TR11 = 25% kolanut pod husk + 75% NPK, TR12 = 25% coconut pod husk + 75% NPK, TR13 = 25% cocoa pod husk + 75% NPK

Table 3 Effect of sole and integrated use of plant residues on root dry weight, shoot dry weight, total biomass and root/shoot ratio of tomato

Treatment	Dry matter			
	Root dry weight (g)	Shoot dry weight (g)	Total biomass (g)	Root/shoot ratio
TR0	2.08^{a}	3.86^{d}	5.94^{d}	0.54^{a}
TR1	6.88^{c}	27.03^{a}	32.71^{a}	0.25^{b}
TR2	2.36^{a}	8.05^{c}	10.61^{b}	0.29^{b}
TR3	3.92^{ab}	23.96^{a}	27.92^{a}	0.16^{c}
TR4	3.90^{ab}	23.86^{a}	27.57^{a}	0.17^{c}
TR5	3.78^{ab}	25.40^{a}	29.24^{a}	0.15^{c}
TR6	3.22^{ab}	10.25^{c}	13.45^{c}	0.31^{b}
TR7	3.41^{ab}	19.96^{ab}	23.11^{a}	0.17^{c}
TR8	2.87^{a}	18.15^{ab}	21.07^{a}	0.16^{c}
TR9	2.44^{a}	10.91^{c}	13.46^{b}	0.22^{b}
TR10	2.92^{a}	12.49^{c}	15.44^{b}	0.23^{b}
TR11	2.28^{a}	9.41^{c}	11.64^{b}	0.24^{b}
TR12	2.11^{a}	7.72^{c}	9.83^{b}	0.27^{b}
TR13	2.31^{a}	9.40^{c}	11.66^{b}	0.25^{b}

Values are means of 6 replications. Mean with the same letter(s) in superscript on the same column are not significantly different at p=0.05 (Tukey HSD test). TR0 = control, TR1 = 100% kolanut pod husk, TR2 = 100% coconut pod husk, TR3 = 100% cocoa pod husk, TR4 = 100% NPK, TR5 = 75% kolanut pod husk + 25% NPK, TR6 = 75% coconut pod husk + 25% NPK, TR7 = 75% cocoa pod husk + 25% NPK, TR8 = 50% kolanut pod husk + 50% NPK, TR9 = 50% coconut pod husk + 50% NPK, TR10 = 50% cocoa pod husk + 50% NPK, TR11 = 25% kolanut pod husk + 75% NPK, TR12 = 25% coconut pod husk + 75% NPK, TR13 = 25% cocoa pod husk + 75% NPK

Table 4 Effect of sole and integrated use of plant residues on yield of tomato

Treatment	Yield parameters			
	Number of fruits/plant	Fruit fresh weight (g)	Fruit dry weight (g)	Fruit diameter (cm)
TR0	4.10^{c}	51.59^{d}	4.31^{d}	10.75^{d}
TR1	11.83^{a}	351.62^{a}	18.82^{a}	55.35^{a}
TR2	8.47^{ab}	205.82^{b}	14.12^{b}	43.68^{ab}
TR3	8.00^{ab}	303.31^{ab}	16.19^{ab}	51.38^{a}
TR4	8.33^{ab}	315.63^{ab}	18.23^{ab}	51.28^{a}
TR5	8.50^{ab}	298.12^{ab}	14.52^{ab}	48.65^{a}
TR6	7.37^{ab}	210.76^{c}	12.28^{c}	43.71^{ab}
TR7	8.33^{ab}	284.72^{ab}	14.33^{ab}	47.21^{ab}
TR8	8.33^{ab}	205.15^{b}	11.08^{b}	40.56^{ab}
TR9	7.83^{ab}	101.80^{c}	7.10c	28.83^{c}
TR10	7.50^{ab}	191.17^{c}	6.58^{c}	38.5^{ab}
TR11	7.83^{ab}	196.95^{c}	6.64^{c}	39.76^{ab}
TR12	7.00^{ab}	165.59^{c}	5.32^{c}	36.16^{ab}
TR13	7.67^{ab}	183.17^{c}	6.44^{c}	37.96^{ab}

Values are means of 6 replications; Means with the same letters in superscript on the same column are not significantly different at p=0.05 (Tukey HSD test); TR0 = control, TR1 = 100% kolanut pod husk, TR2 = 100% coconut pod husk, TR3 = 100% cocoa pod husk, TR4 = 100% NPK, TR5 = 75% kolanut pod husk + 25% NPK, TR6 = 75% coconut pod husk + 25% NPK, TR7 = 75% cocoa pod husk + 25% NPK, TR8 = 50% kolanut pod husk + 50% NPK, TR9 = 50% coconut pod husk + 50% NPK, TR10 = 50% cocoa pod husk + 50% NPK, TR11 = 25% kolanut pod husk + 75% NPK, TR12 = 25% coconut pod husk + 75% NPK, TR13 = 25% cocoa pod husk + 75% NPK

Table 5 Effect of sole and integrated use of plant residues on proximate and nutritional compositions of tomato

Treatment	Proximate composition (%)					Nutritional composition (%)					
	NFE	Lipid	Ash	Fibre	Protein	N	P	K	Ca	Mg	Na
TR0	87.16	1.98	0.55	1.63	5.06	0.51	0.45	0.85	0.63	0.23	0.04
TR1	90.64	2.02	0.62	1.77	6.5	1.81	0.49	0.89	0.68	0.35	0.03
TR2	88.44	2.17	0.61	1.84	6.94	1.11	0.51	0.86	0.7	0.34	0.05
TR3	88.51	2.12	0.64	1.92	6.81	1.09	0.48	0.91	0.65	0.29	0.04
TR4	89.91	2.19	0.65	1.87	5.38	0.86	0.52	0.89	0.64	0.31	0.03
TR5	88.83	2.26	0.58	1.83	6.5	1.04	0.57	0.86	0.65	0.32	0.05
TR6	88.72	1.99	0.61	1.74	6.94	1.11	0.62	1.03	0.75	0.35	0.06
TR7	89. 54	2.31	0.64	1.82	5.69	0.91	0.49	0.94	0.74	0.34	0.05
TR8	89.27	2.19	0.67	1.87	6	0.96	0.48	0.89	0.79	0.31	0.06
TR9	89.21	2.26	0.59	1.75	6.19	0.99	0.52	0.91	0.8	0.28	0.04
TR10	89.1	2.15	0.61	1.83	6.31	1.01	0.63	0.86	0.69	0.29	0.03
TR11	89.48	2.17	0.63	1.91	5.81	0.93	0.52	0.87	0.73	0.31	0.06
TR12	89.81	2.21	0.58	1.77	5.63	0.9	0.55	0.89	0.74	0.33	0.06
TR13	88.47	2.25	0.64	1.89	6.75	1.08	0.61	0.91	0.69	0.32	0.04

Values are means of 3 replications; Means with the same letters in superscript on the same column are not significantly different at p=0.05 (Tukey HSD test); TR0 = control, TR1 = 100% kolanut pod husk, TR2 = 100% coconut pod husk, TR3 = 100% cocoa pod husk, TR4 = 100% NPK, TR5 = 75% kolanut pod husk + 25% NPK, TR6 = 75% coconut pod husk + 25% NPK, TR7 = 75% cocoa pod husk + 25% NPK, TR8 = 50% kolanut pod husk + 50% NPK, TR9 = 50% coconut pod husk + 50% NPK, TR10 = 50% cocoa pod husk + 50% NPK, TR11 = 25% kolanut pod husk + 75% NPK, TR12 = 25% coconut pod husk + 75% NPK, TR13 = 25% cocoa pod husk + 75% NPK

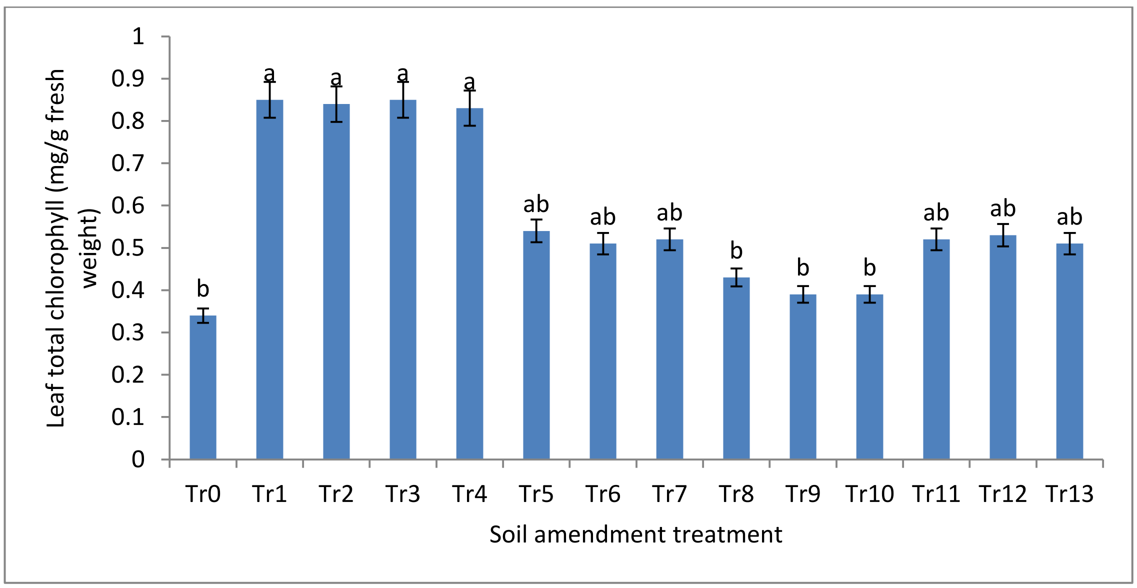

Fig.1 Effect of organic and inorganic fertilizer on leaf total chlorophyll of *Lycopersicum esculentum* (tomato).
Bars represent means of 3 replications. Bars with the same letters are not significantly different at p=0.05 (Tukey HSD test); TR0 = control, TR1 = 100% kolanut pod husk, TR2 = 100% coconut pod husk, TR3 = 100% cocoa pod husk, TR4 = 100% NPK, TR5 = 75% kolanut pod husk + 25% NPK, TR6 = 75% coconut pod husk + 25% NPK, TR7 = 75% cocoa pod husk + 25% NPK, TR8 = 50% kolanut pod husk + 50% NPK, TR9 = 50% coconut pod husk + 50% NPK, TR10 = 50% cocoa pod husk + 50% NPK, TR11 = 25% kolanut pod husk + 75% NPK, TR12 = 25% coconut pod husk + 75% NPK, TR13 = 25% cocoa pod husk + 75% NPK

Discussion

This research revealed that tomato plants showed significant variations in growth parameters among different treatments. It was found that soil amended with fertilizers and plant residues with their integrated use enhanced growth of tomato. Many researchers have also revealed that sole application of organic fertilizer and integration with reduced quantity of inorganic fertilizers increased plant growth in fluted pumpkin (Nwite et al., 2012), cassava (Ojeniyi et al., 2012) and cocoa (Adejobi et al., 2013). Also, the number of leaves per branch and leaf area of Coriander (*Coriandrum sativum*) performed better under farmyard manure and compost than the control (Ahmad et al., 2017). Among the treatments however, growth was best when 100% kolanut pod husk (TR1) was applied. This result did not differ from earlier reports that soil incorporation of plant material such as kolanut pod husk produced adequate nutrients for cocoa seedlings establishment comparable to other treatments including inorganic fertilizer (Adejobi et al., 2013).

Furthermore, it is obvious that the combination of chemical fertilizer and plant residues enhanced the root and shoot dry weight of the tomato plant. Yadana et al. (2009) reported the same findings on *Oryza sativa* grown with farmyard manure. The increase in fresh weight of rice grown with green manure from farm waste and garden waste has also been recorded by Sarwar et al. (2008). Though biomass production was best at TR1, all soil amendment treatments led to more biomass production in terms of root and shoot weight than the control. Similar report was given by Blatt (1991) on *Oryza sativa* L. with the use of inorganic and organic fertilizers to amend soil. In a previous study, it was also found by Ji et al. (2017) that root and shoot growth were improved by 10.2–77.8% and 10.7–33.3% respectively relative to treatment with chemical fertilizer in Chrysanthemum (*Chrysanthemum morifolium*). Adejobi et al. (2013) likewise discovered better growth in cocoa seedlings raised on soil amended with kolanut, cocoa and cowpea pod husks, and NPK fertilizer compared with the control. Enhancement of leaf total chlorophyll by soil amendment has also been affirmed by Ahmad et al. (2017) who recorded higher leaf total chlorophyll in Coriander (*Coriandrum sativum*) under farmyard manure and compost than the control. Purbajanti et al. (2019) likewise discovered that organic manure significantly increased plant height and total chlorophyll contents of peanut (*Arachis hypogaea*). Growth improvement under soil amendment has also been corroborated by Tei et al. (2002) who stated that nitrogen fertilization positively affected tomato vegetative growth and biomass production, as it is associated with increasing photosynthate source capacity. Nutrients absorbed through the root might have been used in leaf development and expansion which provided large surface area for photosynthetic activities thereby increasing photo-assimilates for production of more dry matter in the plant (Ghosh et al., 2004).

The yield parameters of *L. esculentum* generally increased in comparison with the control, with the highest value obtained at 100% kolanut pod husk as well as cocoa pod husk under their integrated use with NPK fertilizer. It was also obtained in this research that the organic materials (koanut pod husk) produced better yield than sole application of NPK. It has been stated that improved yield can be achieved in most crops when soil is amended with organic manure (Celestina et al., 2019). It was also recently discovered that maize growth parameters and yields were all significantly enhanced when grown in soil treated with organic and inorganic fertilizers compared to the control (Jjagwe et al., 2020). Also, Jahn (2005) found that growth and productivity of *Oryza sativa* were positively influenced by organic fertilizer, and concluded that soil amendment with organic fertilizer is a better alternative to applying inorganic fertilizer to improve crop growth and yield. The result is also corroborated by the finding of Guichard et al. (2001) that yield of tomato can be greatly increased with sole or combined application of organic and inorganic fertilizer. Also, soil treatment with compost or its mixture with little quantity of inorganic fertilizer reportedly brought about improved yield and fruit quality in tomato (Togun et al., 2003). Specifically, Abbas et al. (2011) discovered that organic manure in combination with Di-ammonium Phosphate yielded the maximum number of pods/plant in mungbean compared to sole application. Patil (1998) also discovered that vermin-compost with fly ash and inorganic fertilizer gave better yield in groundnut than recommended dose of inorganic fertilizers alone.

The results in this study conform to that of Phibunwatthanawong and Riddech (2019) who reported that organic fertilizers from plant residues (sugarcane leaves) promoted growth in Green Cos Lettuce (*Lactuca sativa* var. *longifolia*) in the same way with chemical fertilizers. Similarly, Ye et al. (2020) likewise discovered production of yield equivalent to what was obtainable under recommended dosage of chemical fertilizer when bio-organic fertilizer was mixed with reduced dosage of inorganic fertilizer. They further explained that nitrate accumulation, vitamin C and total soluble sugar increased by 24%, 57% and 62% respectively in tomato fruits relative to the control. This was attributed to improved soil microbial activity which consequently enhanced soil fertility. They concluded that reduced dosage of chemical fertilizer with bio-organic fertilizer could be used to maximize productivity and good quality yield in tomato. Soil amendment can ameliorate soil by increasing soil available water as a result of improved pore distribution which culminates in improved growth and productivity (Osunsanya & Akinrinola, 2013).

This study further revealed that soil amendments generally improved the nutritional and proximate compositions of *L. esculentum* fruits relative to the control with the exception of Na^+ that was not affected. It was earlier reported that organic fertilizers can improve nutrient content of most crops (Thomas et al., 2019). Bio-organic fertilization was discovered not only to improve growth and yield, it also increased grain nutritional quality in maize (Gao et al., 2020). In agreement with this, Olaniyi and Ajibola (2008) recorded higher protein, fibre, vitamin C, fat and mineral nutrients in tomato plants treated with organic and inorganic fertilizers than those grown in soil without amendment. Likewise, the findings of Olaniyi and Akanbi (2007) has shown that integration of N-fertilizer and organic manure and their sole application relatively improved fibre, crude protein, dry matter, fat and Ca contents of *Telfairia occidentalis* with respect to the control. Ojeniyi et al. (2012) likewise obtained higher values of NPK and Mg in plots of cassava treated with sole application of organic fertilizer than other treatments. Nwite et al. (2012) posited that the ability of the plant materials to improve fruit quality could be as a result of nutrients in the organic materials easily available for plant uptake following mineralization by the activities of soil microorganisms.

Conclusion

In conclusion, tomato grown in soil amended with sole application of kolanut pod husk is capable of producing yield higher than that of sole inorganic NPK fertilizer. Also, sole application of cocoa pod husk as well as integrated use of kolanut or cocoa pod husk with reduced dosage of NPK fertilizer is capable of producing yield achievable under sole application of inorganic NPK fertilizer with good nutritional quality. Yield improvement by soil amendment was achieved through increase in fruit size rather than number of fruits produced.

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