INTERNATIONAL JOURNAL OF ENVIRONMENT

Volume-12, Issue-2, 2023 ISSN 2091-2854

Received: 25 February 2023 *Revised: 22 August 2023* *Accepted: 29 March 2024*

YIELD RESPONSE OF *ABELMOSCHUS ESCULENTUS* AS INFLUENCED BY COMPOST WITH *TITHONIA* LEAVES

S.G.N.D. Samarakoon and Thayamini H. Seran*

Department of Crop Science, Faculty of Agriculture, Eastern University, Chenkalady, Sri Lanka

*Corresponding author: thayaminis@esn.ac.lk

Abstract

Tithonia diversifolia is a genus of flowering plants and its leaves have been used to improve fertility and soil properties by supplying organic matters and nutrients. This experiment was done to study the effect of compost with powdered *Tithonia* leaves on okra yield and to select the optimal quantity of *Tithonia* leaves for obtaining the optimum yield of okra in the sandy regosol soil conditions. This experiment was carried out in a completely randomized design with five replicates with the following treatments; T1 - recommended chemical fertilizers (control), T2 - compost 140 g alone, T3 - compost 140 g + 15 g powdered *Tithonia* leaves (PTL), T4 - compost 140 g + 30 g PTL, T5 - compost 140 g + 45 g PTL, T6 - compost 140 g + 60 g PTL. These fertilizers were applied as the basal application to each polybag (0.07 m^2), while the top dressing was not applied in this experiment. The results revealed that compost with PTL application had effects on the number of pods per plant, the number of seeds per pod, pod length, pod girth, single pod weight, fresh pod weight per plant and marketable pod yield. Further, it was found that T4 was more suitable for obtaining a better marketable pod yield of okra in sandy regosol soil conditions. Based on the results obtained, it can be concluded that 2 kg m^{-2} compost with 0.43 kg m^{-2} powdered *Tithonia* leaves as the basal application could be used in okra cultivation.

Keywords: Compost, marketable yield, okra, organic manure, *Tithonia* leaves

DOI: https://doi.org/10.3126/ije.v12i2.65436

Introduction

Okra (*Abelmoschus esculentus* L.) is a vital vegetable crop which is known as lady's fingers, and it belongs to the family Malvaceae. Okra can be cultivated in different parts of the world, and it is well grown in tropical and sub-tropical climatic conditions. The most suitable temperature ranges 25-35°C for okra cultivation. Therefore, it can be considered as a multipurpose (Mihretu *et al*., 2014) and a warm-season vegetable crop. Okra is cultivated for tender, green and mature pods, and it has a higher demand due to its nutritional value. The immature okra pod has vitamin A and B, and also it is a rich source of minerals like calcium, phosphorous, iron and dietary fiber (Gemede *et al*., 2014). Quality of the seeds, climatic conditions, nutrition, and cultural practices are the key factors determining the growth and yield of okra (Kusvuran, 2012).

In conventional agriculture, farmers use chemical fertilizers to increase crop yield. On the contrary, the use of excess chemical fertilizers affects environmental pollution, soil health, and incidences of pest and diseases (Viharnaa and Seran, 2013). Adediran *et al*. (2004) stated that excessive chemical fertilizers decrease crop productivity since it reduces the soil biological activities and availability of micronutrients. Therefore, farmers are advised to apply organic manures, which are a substitute for chemical fertilizers. Organic manure can improve macronutrients, micronutrients, organic matter content, microorganism diversity and biological activities (Yagi *et al*., 2003); thus, it can increase soil fertility and crop production. In Sri Lanka, most of the rural people are involved in crop cultivation. Farmers can use animal manure, compost, crop residues, plant leaves and other wastes with macro and micronutrients and organic matter for plant growth and their development. Organic manures are eco-friendly (Nadeeka and Seran, 2020). The use of different sources of organic manures is better to provide the required amount of plant nutrients for okra cultivation (Viharna and Seran, 2013).

Tithonia diversifolia is a perennial shrub and belongs to the family Asteraceae (Dutta *et al*., 1993). It is commonly known as the Mexican sunflower, which is originated from Mexico and widely distributed throughout Central and South America, Asia, and Africa (Olabode *et al*., 2007). It releases a high concentration of Nitrogen (Partey *et al*., 2011), and incorporation of *Tithonia* (fresh leaves and young stem) to the soil significantly improved the P, Ca, CEC, K and organic matter content in the soil (Shokalu *et al*., 2010). Sonke (1997) and Muktamar *et al*. (2017) reported that *Tithonia* improves fertility and properties of soil by supplying organic matters, minerals, and other nutrients, and it indirectly boosts the growth and yield of plants. Further, the *Tithonia* leaves contain properties of insecticidal (Adoyo *et al*., 1997) and antimicrobial (Goffin *et al*., 2002). Leaf dry biomass of *Tithonia* contains 3.5% of nitrogen, 0.37% phosphorus and 4.1% potassium (Jama *et al*., 2000). Thus, it can be used as a natural fertilizer and also a biopesticide for the plant. However, information about the usage of *Tithonia* plant leaves as organic manure in crop cultivation is limited. In Western Kenya, farmers use *Tithonia* through composting than directly applying it to the fields

(Setyowati *et al*., 2018). *Tithonia* plants are available in Sri Lanka as well as in other counties. It can be obtained from the farmers' areas in large quantities, and also it is the cheapest material. *Tithonia* plant leaves can be used with compost or other organic manures to supply the nutrients. Organic manures are generally inexpensive and environmentally friendly. This study was done to determine the optimum quantity of powdered *Tithonia diversifolia* added to the compost for obtaining better yield of okra (*Abelmoschus esculentus* L*)* in sandy regosol soil conditions. Research null hypothesis is that compost enriched with powered *Tithonia diversifolia* leaves had no effect on the marketable yield of okra and alternate hypothesis is that it had effect on the marketable yield.

Materials and methods

This experiment was carried out in 2019-2020 as a pot experiment in the Crop Farm, Eastern University, Sri Lanka, which belongs to the low country dry zone in Sri Lanka. It is located between the latitude 7^0 22N and Longitude 81^0 48E (Figure 1). Okra *cv.* Haritha was used in this experiment as one of the recommended varieties in Sri Lanka and mainly tolerant for the yellow vein mosaic disease. It was laid out in a completely randomized design with six treatments with five replications. Each replication had two plants. Treatments were recommended chemical fertilizers (T1 as control) and also compost (0.56% N, 0.48% P_2O_5, 0.62% K_2O) 140 g (equivalent to 2 kg m^{-2}) alone (T2) or in combination with powdered *Tithonia* leaves 15 g (T3), 30 g (T4), 45 g (T5) and 60 g (T6).

The *Tithonia diversifolia* leaves were collected from the Eastern province of Sri Lanka, and the fresh leaves were cleaned subsequently. They were cut into 2-3 cm long pieces. They were air dried under sunlight for one week. The dried leaves were powdered by using a blender (Magic Bullet blender, USA) and it was sieved by a 500 µm mesh sieve as described by Shiriki *et al*. (2015) and stored at room temperature. The polybags (0.07 m^2) were filled with soil. Compost and *Tithonia* airdried leaf powder were applied to each polybag one week before seeding. At the same time, NPK chemical fertilizers were added one day before seeding as basal fertilizers. Top dressing was not applied to any treatment to determine the effect of powdered *Tithonia* leaves on the growth and yield of okra.

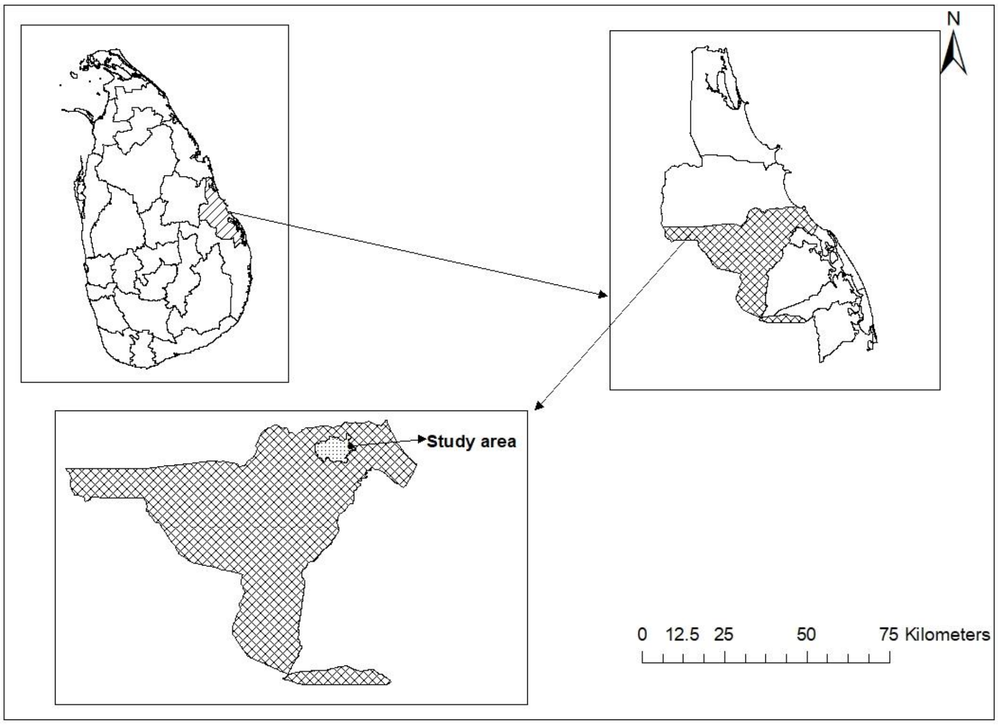

Figure 1: Location map of study area.

All the polybags were arranged in the experiment area with a spacing of 90 cm between rows and 60 cm within a row as recommended by the Department of Agriculture, Sri Lanka. Okra seeds cv Haritha were soaked in water for 12 hours, and they were sown at two seeds per bag with 2 cm depth. The thinning practice was done to maintain one plant per polybag, and other cultural practices were done as recommended by the Department of Agriculture, Sri Lanka. Growth parameters were taken every two weeks interval, and all the yield parameters were taken at the harvesting stage. A statistical software package (SAS 9.1 version) was used for statistical analysis. The treatment means were compared at 5% significant level using Tukey's Honestly Significant Difference Test.

Results and discussion

Plant height and number of leaves

There was no remarkable difference between treatments ($P>0.05$) on plant height and number of leaves at the 4th week after the seeding of okra among the treatments (Table 1). Plant height was high in T6, which was treated with compost and 60 g of leaf powder per polybag, and the plant height was low in T1, which was used as the control. The mean values of the plant height ranged from 20.28 cm to 23.67 cm. The finding is supported by Setyowati *et al.* (2018), who stated that as the application rate of *Tithonia* leaf powder increases to a specific limit, the plant height increases in cauliflower plant by providing nutrients for plant growth than the chemical fertilizers. *Tithonia* consists of various chemical compounds, including alkaloids, saponins, phenols and other substances (Taiwo and Makinde, 2005), accelerating plant growth and development (Nguemezi and Dzukam, 2016). Odeyemi *et al*. (2014) also reported that cowpea plants in *Tithonia* added soil were taller than the other plants due to their ability to improve the soil properties. In the present study, the plant treated with powdered *Tithonia* had a high value in plant height compared to the control. It may be due to the availability of the essential nutrients in the *Tithonia* leaf powder, which accelerate the cell division and elongation for increasing the plant height. Plant height is a foremost determinant of a plant's ability to compete for light (Falster and Westoby, 2003) which is one of the required inputs for photosynthesis.

Table 1: Effect of compost enriched with powered *Tithonia* leaves on plant height and number of leaves of okra per plant at 4th week after seeding.

Treatments	Treatment code	Plant height (cm)	Number of leaves per plant
*NPK chemical fertilizers	T1	20.28±0.68	6.3±0.60
Compost 140 g + TL 0 g	T2	21.55±0.38	6.8±0.44
Compost 140 g + TL 15 g	T3	22.22±0.84	6.5±0.28
Compost 140 g + TL 30 g	T4	22.15±1.05	7.0±0.28
Compost 140 g + TL 45 g	T5	22.98±0.72	7.0±0.28
Compost 140 g + TL 60 g	T6	23.67±1.66	6.2±0.44
F Test (P value)		0.235	0.595
CV		14.86	16.37

*Recommended NPK chemical fertilizers as basal application

TL: Powdered *Tithonia* leaves. Values represent ± standard errors of five replicates.

The number (7) of leaves per plant was a maximum value in T4 and T5; meanwhile, all the other treatments except T6 showed a relatively higher number of leaves than the T1 (control). The composted *Tithonia* significantly boosted the leaf number per tomato plant (Babajide *et al*., 2008). Organic manures enhance the availability of nitrogen, phosphorous, potassium and other essential minerals and nutrients necessary for the growth and development of plants (Palm *et al*., 2001). Imthiyas and Seran (2015) noted that applying 20 t ha^{-1} compost as basal with recommended chemical fertilizers as top dressing attains high leaf production than chemical fertilizers alone. The high number of leaves and most giant leaves of cowpea were attained by applying the powdered *Tithonia* leaves (Odeyemi *et al*., 2014). Several studies showed that *Tithonia* increases soil physical and chemical properties significantly. *Tithonia* has comparatively higher nutrient concentrations due to its ability to absorb a high amount of nutrients from the soil (Jama *et al*., 2000).

Leaf area

The compost with *Tithonia* leaf powder had no significant effect on the leaf area of the okra plant at the 4th week after the seeding (Figure 2). Treatment T4 had the highest leaf area (401.36 cm^2), whereas T1 exhibited the minimum leaf area (293.85 cm^2). The result is under Odeyemi *et al.* (2014), who observed that the plants treated with *Tithonia* leaf powder were a significantly higher in leaf area than the other cowpea plants. This study also noted that all plants grown in *Tithonia* leaf powder showed a higher leaf area than the control treatment. *Tithonia* enhances soil properties and fertility. Thereby, it supplies organic matters, minerals, and other nutrients for increasing crop production (Muktamar *et al.*, 2017). The entire plant photosynthesis depends on the total leaf area of the plant (Iglesias *et al.*, 2002). Thus, the number of leaves and leaf area per plant are relatively imperative in photosynthesis, is a vital physiological process for the accumulation of dry matter in plants. Kang and Iersel (2004) reported that a larger leaf area was recorded in plants grown with higher fertilizer application.

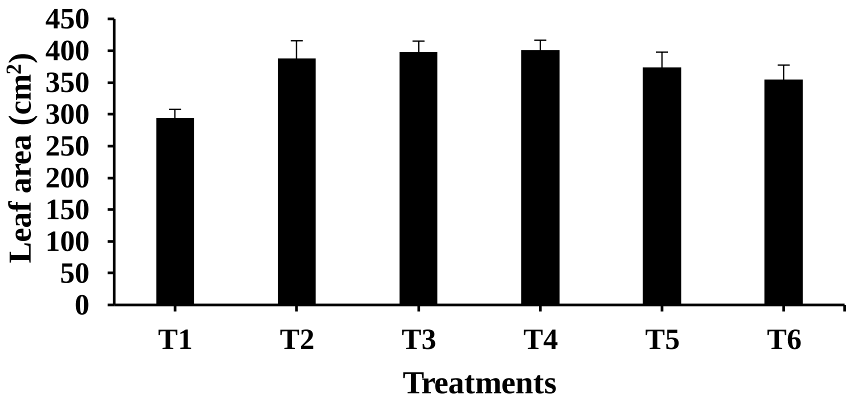

Figure 2: Influence of compost enriched with powered *Tithonia* leaves on Leaf area of okra per plant at 4th week after seeding.

Number of flowers

According to the findings in this experiment, there was no significant differences (P>0.05) among the treatments (Figure 3). However, it was noticed that the application of powdered *Tithonia* leaves enhanced the number of flowers compared to the control treatment. At six weeks after seeding, *Tithonia* leaf powder increased the number of flowers per plant in T4 (1.8) followed by T2 (1.7) and T3 (1.7). The result is in per with the findings of Nguemezi and Dzukam (2016) reported that extracts and powders of *Tithonia* boost the crop growth, time of flowering, number of flowering and yield of tomato plants. Moreover, the *Tithonia* compost speeds up the time of flowering in cauliflower at a rate of 25 t ha^{-1} (Setyowati *et al.*, 2018). Thus, *Tithonia* shows the plant growth-promoting ability (Olabode *et al.*, 2007). Hence, the increment of flowering in okra may be due to the nutrients and other substances available in *Tithonia leaf* powder.

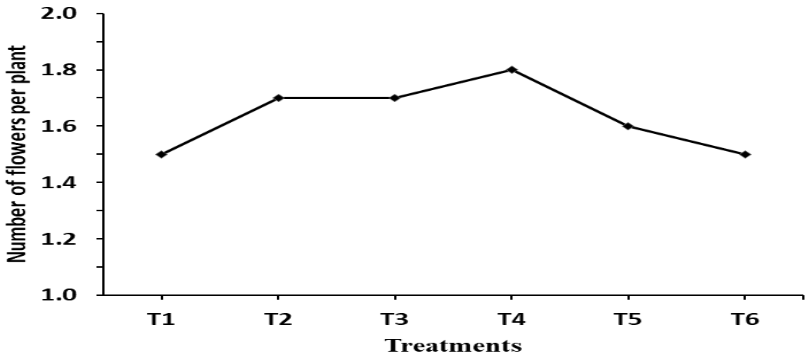

Figure 3: Effect of compost enriched with powered *Tithonia* leaves on the number of flowers in okra per plant at 6th week after seeding.

Number of marketable pods

The data presented in Table 2 shows that the application of powdered *Tithonia* leaves significantly influenced ($P<0.05$) the number of marketable pods per plant. The minimum number of pods per plant was attained in T1 (3.6), while the maximum number of pods per plant was recorded in T4 (8.4), followed by T3 (8.0) and T5 (7.4). It was also observed that there was no considerable difference between T1 and T2. *Tithonia* is rapidly decomposed, and it may accelerate the adding of organic manure to the soil for releasing plant nutrients as available forms rapidly (Partey *et al*., 2011). Further, it confirmed with Viharnaa and Seran (2013), who stated that the application of organic manures might enhance the soil properties resulting in a better supply of macro and micronutrients for better growth and yield of okra. Jama *et al*. (2000) stated that *Tithonia* contains significantly high nitrogen, phosphorous and potassium contents to use as an impressive soil amendment for increasing soil fertility and crop yield. Shokalu *et al*. (2010) also reported that the phosphorus content of soil could be significantly increased by applying *Tithonia* to the soil. This may direct to improve the production of marketable pods in okra.

Table 2: Number of marketable pods per plant and number of seeds per pod of okra as influenced by compost enriched with powered *Tithonia* leaves.

Treatment	Number of pods (>6 cm length) per plant	Seed number range per pod	Number of seeds per pod
T1	3.6 ± 0.24^{b}	9-18	13.0 ± 0.75^{c}
T2	6.6 ± 0.14^{ab}	13-37	24.2 ± 2.11^{bc}
T3	8.0 ± 0.70^{a}	10-41	26.3 ± 1.06^{b}
T4	8.4 ± 0.39^{a}	14-46	29.0 ± 2.00^{ab}
T5	7.4 ± 0.67^{a}	17-63	40.5 ± 4.44^{a}
T6	6.8 ± 0.17^{ab}	15-53	34.4 ± 4.36^{ab}
F Test (P value)	<0.0001	-	<0.0001
CV%	15.77		22.91

Values represent ± standard errors of five replicates. Means followed by the same letter are not significantly different from each other at 5% significant level according to Tukey's Honestly Significant Difference Test.

Pod length

The results showed that the pod length of the okra at the harvest, was significantly varied ($P<0.05$) by the application of compost with powdered *Tithonia* leaves. The highest pod length was recorded in T5 (17.0 cm) when compared to the other treatments and there was no a remarkable difference among the treatments T4, T5, and T6 (Table 3). The lowest length of the pod was observed in T1 (10.94 cm) among the treatments. The application of *Tithonia* at the rate of 45 g per polybag increased the pod length in higher value compared to the control. *Tithonia* can be used as a replacement for N fertilizer like urea (Opala *et al*., 2015) and it may cause to enlarge the size of the pods. Extracts and powdered *Tithonia* influenced to increase the fruit size and yield of tomato due to the enhancing of N in soil (Nguemezi and Dzukam, 2016). The range of the pod length in each treatment is given in Table 3. The pod length ranged from 12.8 cm to 18.5 cm in T5 which had a higher value of average pod length in the present experiment. In general, an increase in the pod length leads to enhance the pod yield of okra.

Table 3: Effect of compost enriched with *Tithonia* leaf powder on length and girth of the marketable pod of okra.

Treatment	Pod length (cm)	Pod length range (cm)	Pod girth (cm)	Pod girth range (cm)
T1	10.94 ± 0.65^{d}	9.0-12.6	4.60 ± 0.18^{b}	4-5-1.0
T2	12.16 ± 0.79^{cd}	11.0-15.3	5.22 ± 0.17^{ab}	4.7-5.8
T3	13.08 ± 0.47^{bcd}	11.7-14.6	5.20 ± 0.10^{ab}	4.8-5.4
T4	15.80 ± 0.96^{ab}	12.3-18.0	5.68 ± 0.25^{a}	4.9-6.3
T5	17.00 ± 1.07^{a}	12.8-18.5	5.68 ± 0.22^{a}	5.1-6.3
T6	15.70 ± 0.82^{abc}	13.2-17.8	5.44 ± 0.17^{ab}	4.9-5.9
Grand mean	14.11 ± 0.79		5.30 ± 0.18	
F Test (P value)	<0.0001	-	0.0057	-
CV%	13.03		8.14	

Values represent ± standard errors of five replicates. Means followed by the same letter are not significantly different from each other at 5% significant level according to Tukey's Honestly Significant Difference Test.

Average pod girth

As shown in Table 3, there was a remarkable dissimilarity ($P<0.05$) in the girth of pods at harvest among the treatments. It exhibited that the *Tithonia* leaf powder had a notable role in the pod girth. The minimum pod girth was attained in T1 (4.6 cm) while maximum pod girth was noted in T4 and T5 (5.68 cm). The pod girth of the treatments T2-T6 was higher than the T1 (control). This may be due to the positive effect of compost alone or in combination of *Tithonia* leaf powder added to the soil which release nutrients slowly in available forms to the okra plants. Further, the range of the pod girth was recorded in each treatment (Table 3). The pod girth ranged 4.9 cm - 6.3 cm in T4 and 5.1 cm - 6.3 cm in T5.

Number of seeds per pod

The number of okra seeds per pod was considerably different ($P<0.05$) by the application of *Tithonia* at the harvest (Table 2). The minimum number of seeds per pod was attained in the control treatment (13.0) and maximum number of seeds was recorded in T5 (40.5). All the plants treated with compost with the powdered *Tithonia* leaves had notably higher a number of seeds than the control treatment. Among the tested treatments, the seed number per pod ranged from 9 to 18 in T1 and it was from 17 to 63 in T5. This might be due to the slow releasing of nutrients from the compost and powdered *Tithonia* leaves for seed formation and its development. Thus, the seed number per pod increased compared to the control treatment. Normally NPK chemical fertilizers release nutrients quickly but available for a short time in the soil especially in the sandy soil conversely, compost with *Tithonia* leaves may remain in the soil for a longer period as stated by Adeniyan and Ojeniyi (2003). Volatile components in sundried botanicals may act as repellents to the storage pests (Seran and Raveenranath, 2000). Thus, the seeds harvested from the plants grown in *Tithonia* leave powder might be less damage by the pests.

Fresh pod weight

The results revealed that the pod weight of okra was significantly differed ($P<0.05$) by the application of the powdered *Tithonia* leaves (Table 4). At the harvest, the minimum pod weight was noted in T1 (7.26 g) which was the control treatment meanwhile the maximum weight of fresh pod was achieved in T5 (17.40 g) followed by T6 (15.86 g), T4 (15.44 g), and T3 (12.88 g). The increase in pod weight may be due to the incorporation of *Tithonia* leaf powder to soil which may improve soil fertility for increasing weight of okra pods. This is in accordance with Hafifah *et al.* (2016) who stated that application of *Tithonia. diversifolia* green manure with cow manure can increase physical and chemical properties of soil and enhanced yield of cauliflower. It was further noted that there was a remarkable difference ($P<0.05$) in fresh pod weight per plant among the treatments in which the T4 (130.28 g) had highest value and T1 (26.16 g) exhibited least pod weight per plant. The high pod weights per plant were also recorded in T5 (128.66 g), T6 (107.22 g) and T3 (101.94 g) compared to T1 (control). Partey *et al*. (2011) stated that green biomass of *Tithonia* has high N concentration and rapid decomposition ability to supply nitrogen to the crop.

Table 4: Marketable pod weight and yield of okra as influenced by compost enriched with powered *Tithonia* leaf powder.

Treatment	Fresh pod weight (g)	Fresh pod weight (g) per plant	Marketable pod yield (kg/ha)
T1	7.26±0.23^{d}	26.16±2.07^{c}	720.67±50.76^{c}
T2	10.00±0.70^{cd}	65.42±3.12^{bc}	1810.72±80.68^{bc}
T3	12.88±0.68^{bc}	101.94±7.24^{ab}	2830.17±200.12^{ab}
T4	15.44±1.78^{ab}	130.28±17.02^{a}	3610.89±470.27^{a}
T5	17.40±1.00^{a}	128.66±12.79^{a}	3570.39±350.54^{a}
T6	15.86±1.07^{ab}	107.22±7.55^{ab}	2970.83±200.99^{ab}
Grand mean	13.14±0.91	93.28±9.96	2590.11±230.06
F Test (P value)	<0.0001	-<0.0001	<0.0001
CV%	17.56	23.51	23.51

Values represent ± standard errors of five replicates. Means followed by the same letter are not significantly different from each other at 5% significant level according to Tukey's Honestly Significant Difference Test.

Marketable pod yield

The effect of compost with powdered *Tithonia l*eaves on the total marketable pod yield is shown in Table 4. The maximum yield was achieved in T4 (3610.89 g) followed by T5 (3570.39 g) and T6 (2970.83 g). The application of different amounts of powdered leaves was remarkably influenced (P<0.05) to the pod yield per square meter. Thus, 30 g *Tithonia* leaves per polybag affected the marketable pod yield of okra. It may be due to the essential nutrients in compost and *Tithonia l*eaves for increasing the marketable yield of okra. This is in line with Gachengo (1999), who reported that incorporating fresh *Tithonia* biomass at the equivalent of 5 t dry matter per hectare increased the maize yield. Gayathri and Seran (2020) stated that the combined use of leaf mould and banana peel with a reduced level of chemical fertilizers remarkably increased the fruit yield of okra than the control treatment (chemical fertilizer alone) in sandy regosal. Hafifah *et al*. (2016) reported that the addition of the *Tithonia* green manure to the soil raises the total N, available P and the organic C, which may increase the pod number per plant. Thus, organic manures, particularly with botanical materials, may provide the macro and micronutrients and other growth-promoting substances for the increasing crop production in okra plants.

Correlation between parameters

The findings of this research showed a relationship between the pod length and pod girth of okra at harvest. As the pod length increased, the pod girth also increased positively. Increasing pod length with the pod girth persuades for increasing pod size. There was a positive correlation between pod length and pod girth in T4 (r=0.7778), as shown in Figure 4. Further, it was observed that the pod length and seed number of seeds per pod exhibited a positive correlation (Figure 5). The pod length increased with increasing the pod size. Subsequently, it leads to an increase in the seed numbers in the pod. Moreover, a significant relationship was noted between the pod length and single pod weight. Based on the results obtained, single pod weight was slowly increased as the pod length increased. There was a positive correlation among these two parameters (Figure 6). The increase in pod weight may be due to powdered *Tithonia* leaves, which eventually leads to increasing the marketable pod yield of okra in this study.

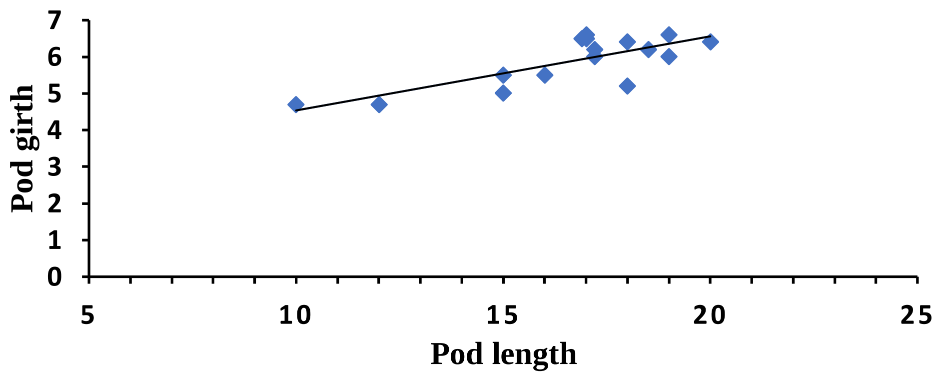

Figure 4: Correlation between average pod girth and pod length in T4 (r=0.7778).

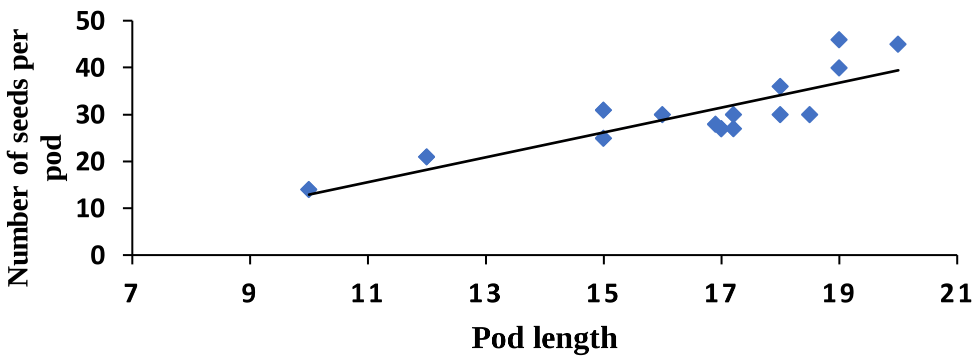

Figure 5: Correlation between average pod length and pod seed number per pod in treatment 4 (r=0.8433).

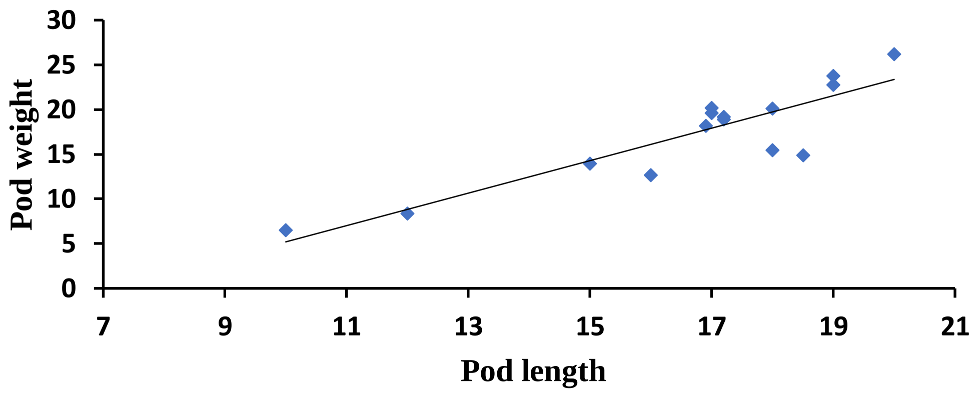

Figure 6: Correlation between average pod length and single pod weight in treatment 4 (r=0.8858).

Conclusion

Application of compost with the powdered *Tithonia* leaves had considerable effects on some tested parameters of the yield of okra (*Abelmoschus esculentus* (L.) Moench). The results confirmed that application of powdered *Tithonia* leaves had significant variations (P<0.05) on the number of pods per plant, the number of seeds per pod, length of a pod, a girth of the pod, weight of pod, pod weight per plant and pod yield per square meter. Therefore, 2 kg m^{-2} compost with 0.43 kg m^{-2} powdered *Tithonia diversifolia* leaves can be recommended as an organic fertilizer for growing okra crop in sandy regosol soil conditions.

Conflict of interest

The authors declare no conflicts of interest.

Authors' contribution

S.G.N.D. Samarakoon and T.H. Seran contributed equally to the research design, data collection, analysis and drafting the manuscript. The final manuscript was reviewed and approved by all the authors.

Acknowledgment

The authors would like to thank Department of Crop Science for their help in use of laboratory facilities.

References

Adediran, J.A., Taiwo, L.B., Akande, M.O., Sobulo, R.A., Idowu, O.J., 2004. Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. *Journal of Plant Nutrition,* 27(7): 1163-1181. https://doi.org/10.1081/PLN-120038542

Adeniyan, O.N., Ojeniyi, S.O., 2003. Comparative effectiveness of different levels of poultry manure with NPK fertilizers on residual soil fertility, nutrient uptake and yield of maize. *Moor Journal of Agricultural Research*, 4(2): 191-197. https://doi.org/10.4314/mjar.v4i2.31775

Adoyo, F., Mukalama, J.B., Enyola, M., 1997. Using *Tithonia* concoctions for termite control in Busia district, Kenya. *ILEIA Newsletter*, 13(4): 24-25.

Babajide, P.A., Olabode, O.S., Akanbi, W.B., Olatunji, O.O., Ewetola, E.A., 2008. Influence on composted *Tithonia* biomass and N-mineral fertilizer on soil physiochemical properties and performance of tomato (*Lycopersicum esculentus*). *Research Journal of Agronomy*, 2(4): 101-106.

Dutta, P., Chaudhuri, R.P., Sharma, R.P., 1993. Insect feeding deterrents from *Tithonia diversifolia* (Hemsl) Gray. *Journal of Environmental Biology*, 14(1): 27-33.

Falster, D.S., Westoby, M., 2003. Plant height and evolutionary games. *Trends in Ecology and Evolution*, 18(7): 337-343. https://doi.org/10.1016/S0169-5347(03)00061-2

Gachengo, C.N., Palm, C.A., Jama, B., Othieno, C., 1999. *Tithonia* and Senna green manures and inorganic fertilizers as phosphorus sources for maize in western Kenya. *Agroforestry Sytems*, 44(1): 21-36. https://doi.org/10.1023/A:1006123404071

Gayathri, U.H.N., Seran, T.H., 2020. Okra (*Abelmoschus esculentus* L.) yield influenced by *Albizia* leaf mould and banana peel with half dosage of NP chemical fertilizers. *Bangladesh Journal of Scientific Industrial Research*, 55(4): 273-282. https://doi.org/10.3329/bjsir.v55i4.50966

Gemede, H.F., Ratta, N., Haki, G.D., Woldegiorgis F.B.A.Z., 2014. Nutritional quality and health benefits of okra (*Abelmoschus esculentus*): A review. *Global Journal of Medical Research*, 14(5): 29.

Goffin, E., Ziemons, E., Mol, P., Madureira, M., Martins, A., Cunha, A., 2002. *In vitro* antiplasmodial activity of *Tithonia diversifolia* and identification of its main active constituent: tagitinin C. *Planta Medica*, 68(6): 543-545. https://doi.org/10.1055/s-2002-32552.

Hafifah, H., Maghfoer, S., Maghfoer, M.D., Prasetya, B., 2016. The potential of *Tithonia diversifolia* green manure for improving soil quality for cauliflower (*Brassica oleracea* var. Brotrytis L.). *Journal of Degraded and Mining Lands Management*, 3: 499-506. https://doi.org/10.15243/jdmlm.2016.032.499

Iglesias, D.J., Lliso, I., Tadeo, F.R., Talon, M., 2002. Regulation of photosynthesis through source: sink imbalance in citrus mediated by carbohydrate content in leaves. *Physiologia Plantarum*, 116(4): 563-572. https://doi.org/10.1034/j.1399-3054.2002.1160416.x

Imthiyas, M.S.M., Seran, T.H., 2015. Influence of compost with reduced level of chemical fertilizers on the accumulation of dry matter in leaves of radish (*Raphanus sativus* L.). *Journal of Agricultural Sciences and Engineering,* 1(1); 1-4.

Jama, B., Palm, C.A., Buresh, R.J., Niang, A., Gachengo, C., Nziguheba, G., Amadalo, B., 2000. *Tithonia diversifolia* as a green manure for soil fertility improvement in western Kenya:a review. *Agroforestry Systems*, 49: 201-221.

Kang, J. G., Iersel, M.W.V., 2004. Nutrient solution concentration affects shoot, root ratio, leaf area ratio and growth of sub irrigated salvia (*Salvia splendens*). *HortScience*, 39(1): 49-54. https://doi.org/10.21273/HORTSCI.39.1.49

Kusvuran, S., 2012. Influence of drought stress on growth, ion accumulation and antioxidative enzymes in okra genotypes. *International Journal of Agricultural Biology*, 14(3): 401-406.

Mihretu, Y., Wayessa, G., Adugna, D., 2014. Multivariate analysis among okra (*Abelmoschus esculentus* (L.) moench) collection in south western Ethiopia. *Journal of Plant Science*, 9(2): 43-50. https://doi.org/10.3923/jps.2014.43.50

Muktamar, Z., Sudjatmiko, S., Fahrrurozi, F., Setyowati, N., Chozin, M., 2017. Soil chemical improvement under application of liquid organic fertilizer under closed agriculture system. *Journal of Agricultural Technology*, 13: 1715-1727.

Nadeeka P.W.M., Seran, T.H., 2020**.** The effects of goat manure and sugarcane molasses on the growth and yield of beetroot (*Beta vulgaris* L). *Journal of Agricultural Sciences* (Belgrade), 65(4): 321-335. https://doi.org/10.2298/JAS2004321N

Nguemezi, J.A., Dzukam, H., 2016. Extracts and powders of *Solanum aculeastrum* and *Tithonia diversifolia* induced an improvement of Solanum lycopersicum plant growth development and fruit quality. *International Journal of Biology Research*, 1(5): 43-49.

Odeyemi, I.S., Afolami, S.O., Daramola, F.Y., 2014. Evaluation of *Tithonia diversifolia* and *Chromolaena odorata* residues as potential organic compost materials for the management of Meloidogyne incognita on cowpea (*Vigna unguiculata* L. WALP). *Journal of Agricultural Science and Environment*, 14(1): 73-81. https://doi.org/10.51406/jagse.v14i1.1252

Olabode, O.S., Sola, O., Akanbi, W.B., Adesina, G.O., Babajide, P.A., 2007. Evaluation of *Tithonia diversifolia* (Hemsl.) as gray for soil improvement. *World Journal of Agricultural Sciences*, 3(4): 503-507.

Opala, P.A., Kisinyo, P.O., Nyambati, R.O., 2015. Effect of *Tithonia diversifolia* farm yard manure and urea and phosphate fertilizer application methods on maize yields in western Kenya. *Journal of Agriculture and Rural Development in the Tropics and Sub Tropics*, 116(1): 1-9.

Palm, C.A., Gachengo, C.N., Delve, R.J., Cadisch, G., Giller. K.E., 2001. Organic inputs for soil fertility management in tropical agroecosystems: application of anorganic resource database. *Agricultural Ecosystem. Environment*, 83(1): 27-42.

Partey, S.T., Quashie-sam, S.J., Thevathasan, N.V., Gordon, A.M., 2011. Decomposition and nutrient release patterns of the leaf biomass of the wild sunflower (*Tithonia diversifolia*). *Agroforestry Systems*, 81(2): 123-134. https://doi.org/10.1007/s10457-010-9360-5.

Seran, T.H., Raveenranath, S., 2000. Effect of different forms of rice and botanicals on the development of rice weevil (*Sitophilus oryzae*). *AGRIEAST,* 2; 1-5.

Setyowati, N., Sudjatmiko, S., Muktamar, Z., Fahrurozi, F., Chozin, M., Simatupang, P., 2018. Growth and yield responses of cauliflower on *Tithonia* compost under organic farming practices. *International Journal of Agricultural Technology*, 14(7): 1905-1914.

Shiriki, D., Igyor, M.A., Gernah, D.I., 2015. Nutritional evaluation of complementary food formulations from maize, soybean and peanut fortified with *Moringa oleifera* leaf powder. *Food and Nutrition Sciences*, 6(5): 494-500. http://dx.doi.org/10.4236/fns.2015.65051

Shokalu, A.O., Ojo, A.O., Adewoyin, D.T., Azeez, J.A. (2010). Evaluation of *Tithonia diversofolia* for soil improvement in celosia (*Celosia argentea*) production. *Electronic Journal of Environment Agricultural and Food Chemistry*, 9(5): 951-957.

Sonke, D. (1997). *Tithonia* weed: A potential green manure crop. *Echo Development Notes*, 57:5-6. https://www.echocommunity.org/en/resources/844f65fd-cf8e-4dd6-84d1-da43a977ee8e

Taiwo, L.B., Makinde, J.O., 2005. Influence of water extract of mexican sunflower (*Tithonia diversifolia*) on growth of cowpea (*Vigna unguiculata*). *African Journal of Biotechnology*, 4(4): 355-360.

Viharnaa, S., Seran, T.H., 2013. Effect of cow and poultry manures as basal fertilizers on marketable fruit yield of okra (*Abelmoschus esculentus* L.) *Tropical Agricultural Research and Extension,* 16(1): 3 pages.

Yagi R., Ferreira, M.E., Cruz, M.C.P., Barbosa, J.C., 2003. Organic matter fractions and soil fertility under influence of liming, vermicopmpost and cattle manure. *Scientia Agricola*, 60(3): 549-557. https://doi.org/10.1590/S0103-90162003000300021