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RESEARCH ARTICLE

PLANT GROWTH, FOLIAGE SENESCENCE AND RHIZOME YIELD OF TURMERIC (*Curcuma domestica* L.) AS AFFECTED BY INORGANIC AND ORGANIC FERTILIZERS

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Abstract

Integrated plant nutrient management is one of the key components of sustainable agriculture. It reduces the cost of production while enhancing the revenue of growers. The present study was conducted to examine the effect of sole and combine applications of inorganic fertilizer and organic fertilizers on plant growth, foliage senescence and rhizome yield of turmeric (*Curcuma domestica* L.) in container gardening. Eight treatments comprise sole applications of different types of organic fertilizers including vermicompost, compost and matured cow dung, and inorganic fertilizer schedule recommended by the Department of Export Agriculture, Sri Lanka together with combinations of inorganic and organic fertilizers. Sand: topsoil: partially burned paddy husk (1:1:1 v/v) were used to fill the black plastic pots with 30 cm in diameter. Due to the variation of shade of the experimental site, the experiment was setup as a randomized complete block design with three replicates. The number of leaves per shoot, leaf length (cm), leaf width (cm), height of the pseudo stem (cm), number of shoots per pot were taken five months after planting while the number of primary fingers/clump, number of secondary fingers/clump, fresh and dry weight of rhizomes/pot (g) were taken at harvest. Foliage senescence as visual senescence score was recorded from 32 weeks after plant establishment until foliage became dry. All measured quantitative parameters were significantly different between treatments, where the greater values were recorded when plants were treated with equal proportions of inorganic fertilizer and vermicompost as an organic fertilizer while the foliage senescence took a longer period in the same treatment when compared to other treatments. This might be due continuous supply of nutrients through an integrated approach of nutrient management and modification of physical and microbiological properties of the growth substrate by vermicompost application. Poor plant growth, early senescence and low fresh and dry yield of rhizomes were reported when plants were grown without inorganic or organic fertilizers may be due to an insufficient supply of nutrients to fulfil the demand of plant growth and development. Combine application of vermicompost and inorganic fertilizer could be considered as a promising combination of fertilizers for the growth and yield of turmeric under integrated plant nutrient management.

Keywords: Compost, Integrated plant nutrient management, Inorganic fertilizer, Matured cow dung, Turmeric, Vermicompost

INTRODUCTION

The use of organic manure and organic amendments in turmeric cultivation plays a vital role in improving the quality of turmeric as well as enhancing soil health. Turmeric is closely related to human diets and hence the demand for organically grown turmeric is increasing tremendously worldwide. Turmeric (*Curcuma longa* L.) belongs to the family *Zingiberaceae* rich in phosphorus, calcium, iron and vitamin A (Jabborova *et al*. 2021). Turmeric is widely consumed in traditional cuisines and a commercial crop has a broader scope of pharmacological applications due to its anti-inflammatory, anti-mutagenic and anti -carcinogenic properties (Lal 2012). Curcumin has been identified as a potential drug rich in minerals and vitamins (Aggarwal *et al*. 2013). Turmeric is an important crop, cultivated in

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the tropics and the evidence is accessible on the turmeric response to the applications of organic rhizomatous spice widely manure and the beneficial effects of organic fertilization either alone or in combination with synthetic fertilizers on growth, yield and quality of turmeric (Gopalakrishna *et al*. 1997). In the global context, organic farming ensures sustainable production and a quality boost in turmeric (Sadanandan 1998). Similarly, the nutrient requirement of turmeric is quite high due to shallow rooting and it contains appreciable quantities of carbohydrates (69.4%), lipids (5.1%), proteins (6.3%), and fiber (2.6%) (Kumar *et al*. 2013). According to Basak and Jana (2016), organic cultivation is an eco-friendly solution for healthy well-being, and the consumer demand for organically grown turmeric is markedly increasing in the export market (Mohan *et al*. 2013). Organically grown spices fetch higher prices than ordinary packed spices, while there is a great demand from western countries (Sahota 2009). Despite this, the organic production system is designed to work with natural biological cycles and to operate with minimal external inputs (Rigby and Cáceres 2001). Organic cultivation requires a long-term effort by suppressing pests and diseases while throwing continuous challenges (Friedrich and Kassam 2009). The finest method for making optimum use of the resources and producing crops on the best budget is integrated plant nutrient management (IPNM). To address the twin concerns of nutrient excess and nutrient depletion, IPNM, which entails the maintenance of soil fertility to an ideal level for crop productivity to obtain the maximum benefit from all possible sources of plant nutrients, both organic and inorganic, in an integrated manner is crucial. Marginal farmers who cannot afford to provide all crop nutrients through expensive chemical fertilization can benefit from IPNM (Jat *et al*. 2015). The use of IPNM in required quantity assures a special significance in crop production. The IPNM has an immense priority in turmeric which adds advanced value crops for small and marginal farmers in Low Country Wet Zone by improving the productivity of turmeric, and the socio-economic status of the farmers. With this background, the present study was conducted to evaluate the growth and yield of turmeric response to the sole and combine application of inorganic and organic fertilizers including vermicompost, compost and matured cow dung.

MATERIALS AND METHODS

A pot experiment was conducted to compare eight treatments varying with vermicompost, compost and matured cow dung together with inorganic fertilizer. Due to the variation of shade of the experimental site, it was arranged as a randomized completely block design with three replicates. A home garden located at 7.26570N latitude and 79.85910E longitude of 300 m above mean sea level in Kochchikade was selected to conduct the experiment from April 2021 to January 2022. The annual average precipitation of the area is 2500 mm while the highest rainfall, 382 mm received in May. January is the driest month receiving 62 mm of rainfall. The temperature of the warmest month of the area is 32°C and the minimum temperature is 30°C in August. The average daily minimum and maximum temperature of the area are 24℃ and 30.5°C, respectively.

A primary finger rhizome of turmeric (variety Local) weight about 35 g, with 3-5 buds was used as the planting materials and planted 5-7 cm deep of the potting mixture prepared by sand: topsoil: partially burned paddy husk (1:1:1 v/v) filled in the black color plastic pots with 30 cm in diameter. Planting materials were treated with fungicide solution (Mancozeb 1%) before planting. There were eight treatments; T1- Inorganic fertilizer mixture recommended by the Department of Export Agriculture in Sri Lanka (DEA), T2- 100% vermicompost, T3- 100 compost, T4- 100% matured cow dung, T5- 50% DEA recommended fertilizer + 50% Vermicompost, T6- 50% DEA recommended fertilizer + 50% compost, T7- 50% DEA recommended fertilizer + 50% matured cow dung and T8- Without inorganic or organic fertilizer. The fertilizer recommendation of DEA for turmeric was 20 MT/ha of organic fertilizer and 100 kg of TSP as a basal dressing and 65 kg/ha of urea and 100 kg/ha of MOP after one and three months after planting. The amount of vermicompost,

compost and cow dung was calculated based on the volume of the pot and the N requirement of the plant based on the DEA inorganic fertilizer recommendation for nitrogen. N% of the vermicompost, compost and matured cow dung used for the experiment was 1.2, 0.8 and 0.6%, respectively. Vermicompost and compost were prepared at the experimental site using 50% cow dung and 50% kitchen waste. As a basal dressing, 25% of the fertilizer recommended for each treatment was applied. The rest of the fertilizer was applied by equally dividing them into two portions at one and half month and three months after planting. Throughout the experiment, the surface of the pots was covered by straw mulch. Earthing up was done four months after planting until harvesting using topsoil. Watering was done every other day until one month after planting of rhizomes and continued up to October, when necessary, and stopped the supply of water by November. This is to discourage the sprouting of matured rhizomes.

RESULTS AND DISCUSSION

The numbers of leaves per shoot, leaf length, leaf width, height of the pseudo stem, number of primary fingers/clump, number of secondary fingers/clump, fresh and dry weight of rhizomes/pot (*P<0.001*) and number of shoots per pot (*P<0.01*) were significantly different among treatments. The greater number of leaves per shoot was recorded when treated plants with equal proportions of recommended inorganic fertilizer and vermicompost (12.67 cm), 100% matured cow dung (10 cm) and 50% inorganic fertilizer with 50% compost (12.33 cm). When plants did not receive either inorganic or organic fertilizers the lowest number of leaves per shoot of nine was reported (Table 1).

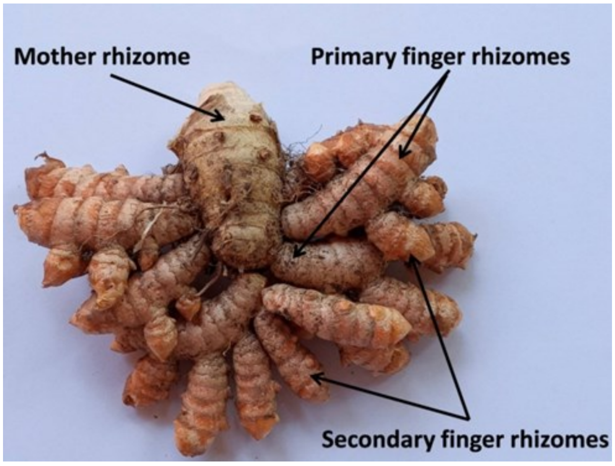

Figure 1: Different types of turmeric rhizomes

Fine-tune with present results, Chamroy*et al.* 2015 found that integrated application of 50% N (urea) + 50% N (Poultry manure), significantly increased turmeric plant height, leaf length, width, leaf area, number of leaves/ plant and number of tillers/clump and recommended organics application along with inorganic fertilizers. Further, Choudhary and Rahi (2018) stated that organic cultivation of high-yielding turmeric is a viable alternative to enhance rhizome productivity, profitability, quality and resource-use efficiency to improve rural livelihoods by making it promising entrepreneurship.

Velmurugan *et al. (*2008) encouraged the use of organic fertilizers for turmeric by stating that the tallest plants, number of leaves, number of tillers, the greatest curing percentage and cured rhizome yield were obtained in the application of farmyard manure + azospirillum + phosphobacteria + VAM (M1 S7). Further, strengthening organic turmeric cultivation, Kamal *et al.* (2012) emphasized that the application of organic manures with neem cake during the turmeric growth stage showed the maximum plant height, number of tillers per plant, leaf number, leaf area, leaf area index, fresh halum weight, fresh root weight, fresh rhizome weight and dry halum weight, dry root weight, dry rhizome weight, total dry matter yield. Pandey *et al.* (2020) suggested that rhizome yield, yield attributing characters and profitability of turmeric were significantly affected by the application of paddy straw mulch along with organic nutrient sources.

The treatment provided equal proportions of inorganic fertilizer and vermicompost as the organic fertilizer enhanced the height of the pseudo stems and reported the value as 68.33 cm. However, it was observed that when plants did not treat with any type of fertilizers produced the shortest pseudo stems (42.50 am) (Table 1). The same treatment which was examined for plant height was observed for the number of shoots per pot where the significantly highest (6.67) and the lowest number of shoots per pot (3.33) were recorded when supplying 50% inorganic fertilizer and 50% vermicompost and no fertilizer for crop growth, respectively (Table 1).

Similar to the height of the pseudo stem, the longest (34.33 cm) and the widest (28.50 cm) leaves of the shoot were recorded in the plants receiving equal proportions of recommended inorganic fertilizer and vermicompost while the shortest (24.50 cm) and the narrowest (18.00 cm) leaves were observed when did not apply any sort of fertilizers (Figure 2).

Table 1: The number of leaves per shoot, number of shoots per pot and the height of the pseudo stem of plants under different treatments after five months of crop establishment

Treatments	Number of leaves per shoot	Number of shoots per pot	Plant height (cm)
T1	7.67^{d}	4.33^{cd}	52.3^{d}
T2	9.33^{bc}	4.67^{bc}	55.52^{bcd}
T3	9.33^{bc}	4.33^{cd}	57.45^{bcd}
T4	12.00^{a}	4.33^{cd}	54.35^{cd}
T5	12.67^{a}	6.67^{a}	68.35^{a}
T6	12.33^{a}	5.33^{bc}	60.37^{b}
T7	11.00^{b}	5.67^{ab}	58.67^{bc}
T8	9.00^{c}	3.33^{d}	42.5^{e}
P value	<0.001	<0.001	<0.001

Furthermore, the greatest number of primary rhizomes (10.67; Figure 3), secondary rhizomes (17.67; Figure 3) and fresh weight of the rhizomes per pot (383.93g; Figure 4) and dry weight of the rhizomes per pot (68.98 g; Figure 5) were recorded in the same treatment that reported the highest shoots per pot.

Kadam and Kamble (2020) tested different organic manures such as yard manure, vermicompost, press mud compost, poultry manure, sugarcane waste, wheat straw, turmeric trash and *jeevamrutha* on yield and curcumin content of turmeric. *It has been found that t*he maximum turmeric dry yield was recorded by application of 25 MT of farm yard manure + 200:100:100 kg $N:P_2O_5:K_2O$ ha^{-1} while vermicompost (11.36 T ha^{-1}) was best for the number of leaves per tiller and number of tillers per plant, plant height and curcumin content. Moreover, Datta *et al.* (2018) found that the application of green leaf manure (*Glyricidia maculata*) at 12 t/ha along with rock phosphate at 0.2 t/ha, wood ash at1 t/ha, Azospirillum at5kg/ha and PSB in 5kg/ ha was the best treatments for yield and quality of ginger and turmeric. Much improvement in physical, chemical and biological properties in the soil was achieved through mulching and organic manuring in turmeric. Hence, the highest rhizome yield with the greatest benefit-cost ratio was gained by applying 100% nitrogen through vermicompost with sulphur and mulching. Similarly, Devi (2008) revealed that the application of vermicompost in 0.4t/ha for turmeric was highly effective followed by carbendazim application in 0.1% recorded the maximum rhizome yields and reduced the turmeric rhizome rot disease level as well. But poultry manure and neem cake were not significantly affected in controlling the rot in turmeric. According to the economic analysis of organic and conventional turmeric cultivations in Tamil Nadu, for the sustainability indicators such as soil conservation, water, power and farmers' economic well-being and livelihood, organic turmeric cultivation is superior in terms of

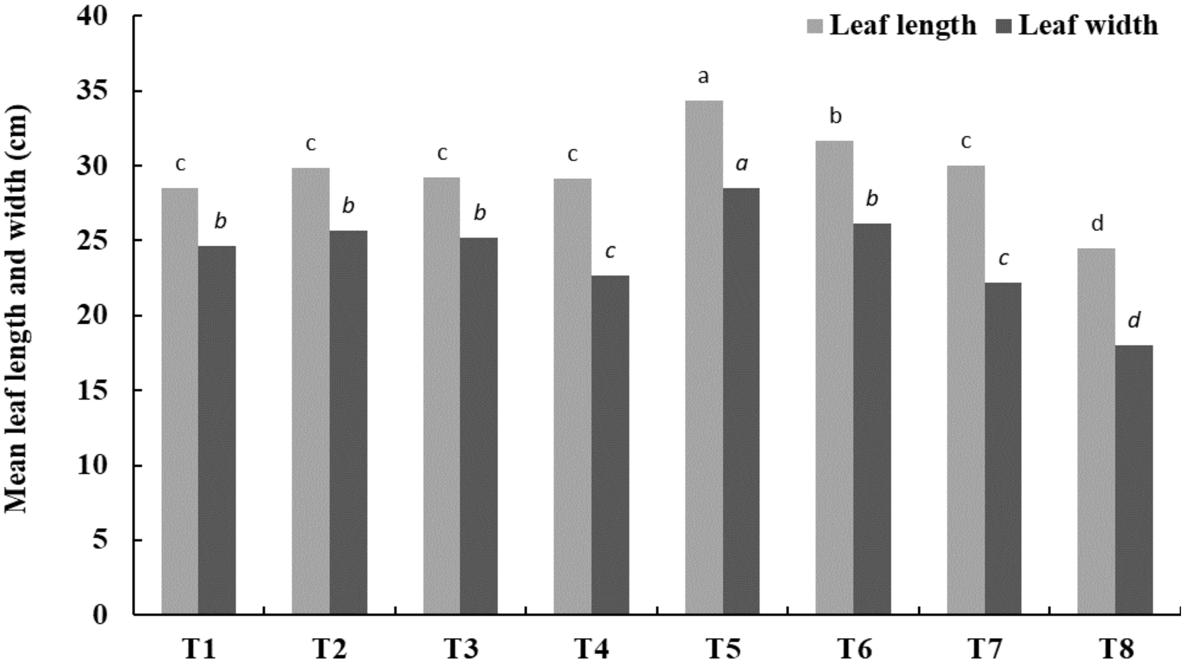

Figure 2: Mean leaf length and leaf width at five months after crop establishment (T1- 100% Recommended Inorganic Fertilizer, T2- 100% Vermicompost, T3- 100% Compost T4- 100% Matured cow dung T5- 50% Recommended Inorganic Fertilizer + 50% Vermicompost, T6- 50% Recommended Inorganic Fertilizer + 50 % compost, T7- 50% Recommended Inorganic Fertilizer + Matured cow dung, T8- Without inorganic or organic Fertilizers). Means with the same letters are not significantly different from each other at α = 0.05

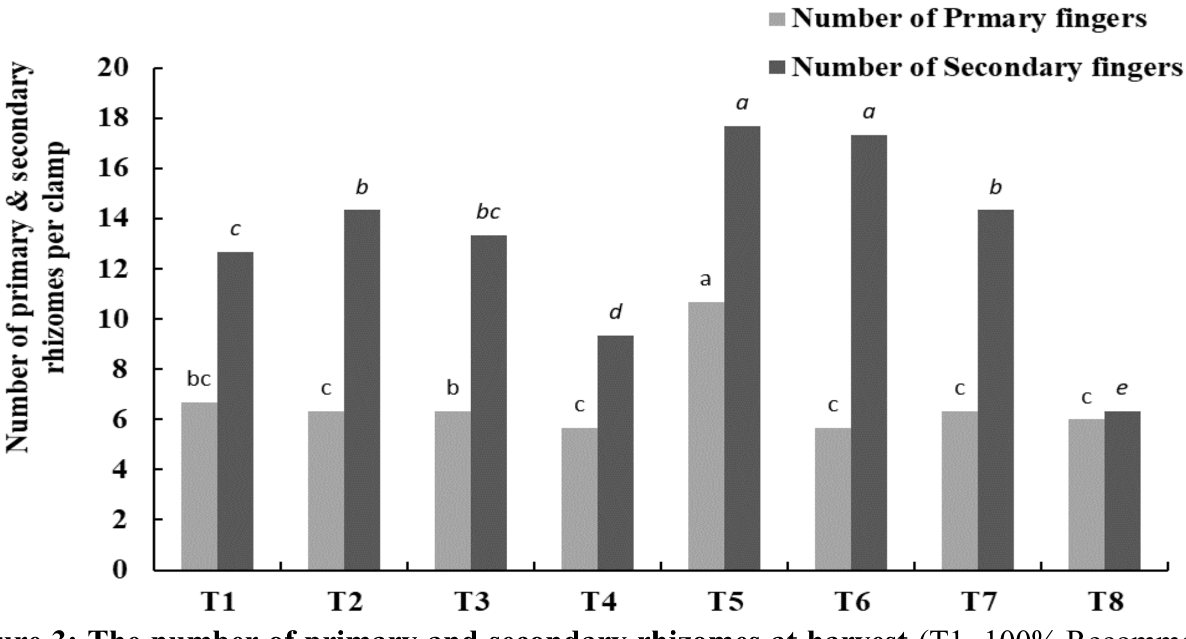

Figure 3: The number of primary and secondary rhizomes at harvest (T1- 100% Recommended Inorganic Fertilizer, T2- 100% Vermicompost, T3- 100% Compost T4- 100% Matured cow dung T5- 50% Recommended Inorganic Fertilizer + 50% Vermicompost, T6- 50% Recommended Inorganic Fertilizer + 50 % compost, T7- 50% Recommended Inorganic Fertilizer + Matured cow dung, T8- Without inorganic or organic Fertilizers). The standard error of the mean is indicated by error bars

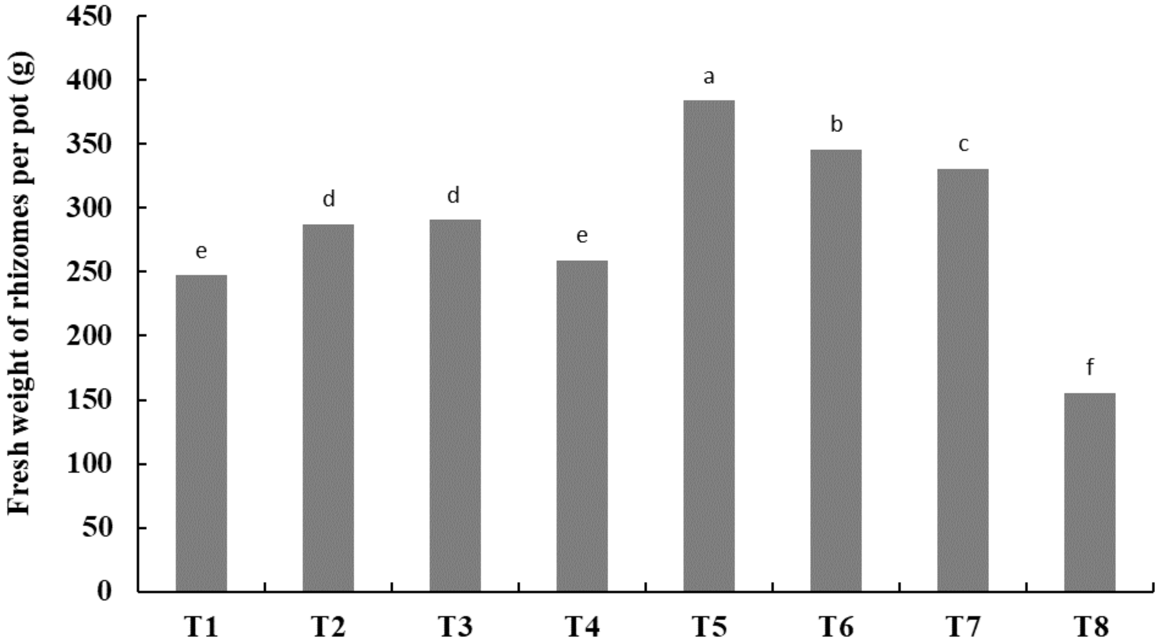

Figure 4: Fresh weight of rhizomes per pot at harvest (T1- 100% Recommended Inorganic Fertilizer, T2- 100% Vermicompost, T3- 100% Compost T4- 100% Matured cow dung T5- 50% Recommended Inorganic Fertilizer + 50% Vermicompost, T6- 50% Recommended Inorganic Fertilizer + 50 % compost, T7- 50% Recommended Inorganic Fertilizer + Matured cow dung, T8- Without inorganic or organic Fertilizers). Means with the same letters are not significantly different from each other at $\alpha = 0.05$

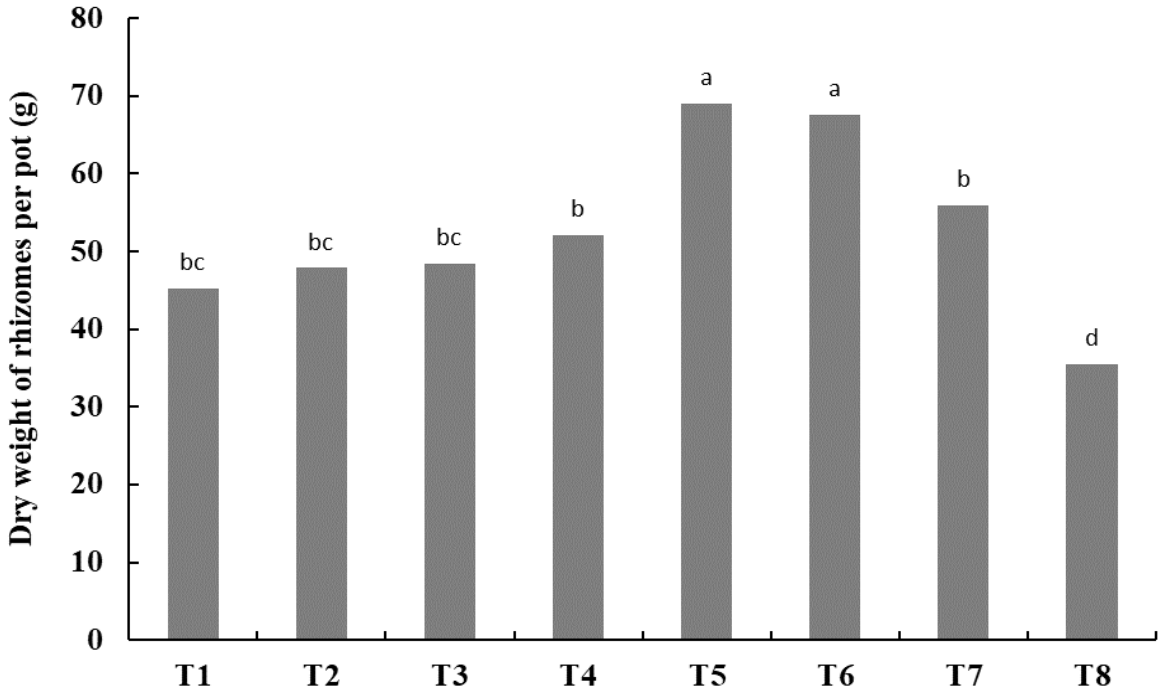

Figure 5: Dry weight of rhizomes per pot at harvest (T1- 100% Recommended Inorganic Fertilizer, T2- 100% Vermicompost, T3- 100% Compost T4- 100% Matured cow dung T5- 50% Recommended Inorganic Fertilizer + 50% Vermicompost, T6- 50% Recommended Inorganic Fertilizer + 50 % compost, T7- 50% Recommended Inorganic Fertilizer + Matured cow dung, T8- Without inorganic or organic Fertilizers). Means with the same letters are not significantly different from each other at $\alpha = 0.05$

economic and livelihood security of the farmer over conventional cultivation (Tholkappian and Devi 2013).

Foliage senescence varied with treatments where rapid senescence of foliage was observed in the plants that did not receive any fertilizer while plants treated with 50% inorganic fertilizer and 50% compost recorded late senescence (Figure 6).

Tripathi *et al*. (2021) emphasized that maximum turmeric yield was observed 50% recommended dose of fertilizer (RDF) + 25% farmyard manure (FYM) + 25% vermicompost and at 0.9 irrigation water

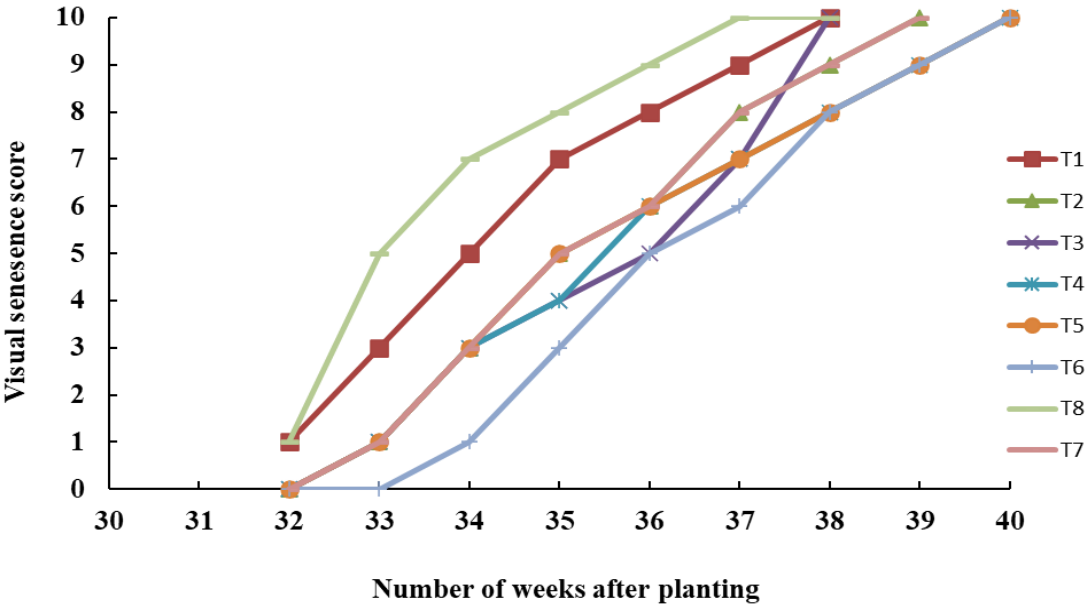

Figure 6: Treatment effect on senescence of the foliage as visual senescence score from 32 weeks after planting until fully senescence (T1- 100% Recommended Inorganic Fertilizer, T2- 100% Vermicompost, T3- 100% Compost T4- 100% Matured cow dung T5- 50% Recommended Inorganic Fertilizer + 50% Vermicompost, T6- 50% Recommended Inorganic Fertilizer + 50 % compost, T7- 50% Recommended Inorganic Fertilizer + Matured cow dung, T8- Without inorganic or organic Fertilizers)

(IW)/cumulative pan evaporation. The higher fresh and cured rhizome yield was obtained under 50% RDF + 25% FYM + 25% vermicompost with 0.9 irrigation water (IW)/ cumulative pan evaporation. Furthermore, supporting the results of the present study, Isaac and Varghese (2016) reported the highest turmeric plant growth in integrating 75% recommended dose of nitrogen as organic manures and 25% as inorganic fertilizers. Rhizome yields were significantly highest (42.71 t ha^{-1}) in the plants treated with vermicompost along with chemical fertilizers followed by poultry manure substitution. Finally, they found that the benefit-cost ratios were between 1.76 and 3.19 between treating inorganic fertilizers alone with vermicompost together with inorganic fertilizers. Figure 7 shows the growth of rhizomes of turmeric under different fertilizer regimes.

CONCLUSIONS

The greater values of the number of leaves per shoot, leaf length (cm), leaf width (cm), height of the pseudo stem (cm), number of shoots per pot, number of primary fingers/ clump, number of secondary fingers/clump, fresh and dry weight of rhizomes/pot (g) and the longest period for maturation and leaf senescence were recorded when treated plants with the equal proportions of inorganic fertilizer and vermicompost as organic fertilizer. According to the results, it can be concluded that 50% inorganic fertilizer and 50% vermicompost can be considered a promising combination of fertilizers for the

Figure 7: Growth of fresh rhizomes under different fertilizer regimes at harvesting
(T1- 100% Recommended Inorganic Fertilizer, T2- 100% Vermicompost, T3- 100% Compost T4- 100% Matured cow dung T5- 50% Recommended Inorganic Fertilizer + 50% Vermicompost, T6- 50% Recommended Inorganic Fertilizer + 50 % compost, T7- 50% Recommended Inorganic Fertilizer + Matured cow dung, T8- Without inorganic or organic Fertilizers)

growth and yield of turmeric under integrated plant nutrient management. However, it is not possible to make a recommendation based on the results of a single experiment. Therefore, it is suggested to conduct a few repeat trials in the future to recommend the best fertilizer regime for the container gardening of turmeric. Furthermore, quality parameters such as the curcumin content of the rhizomes were not analyzed in the present study and it was identified as a limitation.

AUTHOR CONTRIBUTION

KMCF conceptualised & designed the study. KMCF performed the experiment. EMUIE analysed data. KMCF and EMUIE contributed to draft the manuscript. KMCF critically revised the manuscript

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