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Studies on effect of organic manures and biofertilizers on growth, yield and economics of turmeric (*Curcuma longa* L.) varieties

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Abstract
The present investigation on "Studies on effect of organic manures, biofertilizers on growth, yield and quality of Turmeric (*Curcuma longa* L.) varieties" was conducted at College of Horticulture, Rajendranagar, SKLTSHU, Mulugu during 2019-20. The experiment was laid out in Factorial Randomized block design (FRBD) with 2 replications and 18 treatments. The results revealed that among all the organic manures, biofertilizers, varieties and their combinations, among the growth parameters the treatment M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost recorded highest values for plant height (64.40 cm), number of tillers per plant (5.48) and leaf area (404.91 cm^2) at harvest. Among the yield and quality parameters, the treatment M_1 – FYM 45 t/ha + AMC (Arka microbial consortium) 1 lit per quintal manure recorded maximum fresh weight of rhizomes per clump (409.53 g), dry weight of rhizomes per clump (82.2 g), rhizome yield per plant (486.98 g), rhizome yield per plot (24.33 kg). Among the varieties, Salem recorded significantly the highest values for plant height (67.70 cm), number of tillers per plant (5.20), leaf area (524.02 cm^2), fresh weight of rhizomes per clump (482.34 g), dry weight of rhizomes per clump (88.92 g), rhizome yield per plant (670.65 g), rhizome yield per plot (33.51 kg). Among the interaction effects between organic manures, biofertlizers and varieties, the treatment M_3V_1 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + vertical split of mother rhizome of Salem variety recorded maximum plant height (79.47 cm), number of tillers per plant (6.12) and leaf area (576.41 cm^2) at harvest. Among the yield and quality parameters, the treatment M_1V_1 – FYM 45 t/ha + AMC (Arka microbial consortium) 1 lit per quintal manure + vertical split of mother rhizome of Salem variety recorded maximum fresh weight of rhizomes per clump (756.10 g), dry weight of rhizomes per clump (148.15 g), rhizome yield per plant (890.40 g), rhizome yield per plot (44.50 kg). In terms of B: C ratio, application of organic manures and biofertilizers, the treatment M_1V_1 –FYM 45 t/ha + AMC (Arka microbial consortium) 1 lit per quintal manure + First best treatment of first experiment - Salem has recorded maximum benefit cost ratio (5.22).

Keywords: FYM, vermicompost, organic manures, biofertilizers, Arka microbial consortium, Salem

Introduction
Turmeric (*Curcuma longa* L.) is an important, sacred and ancient spice of India. It is a major rhizomatous spice produced and exported from India. Turmeric is an herbaceous perennial plant, native to Tropical South-East Asia, belonging to the family Zingiberaceae, under the order Scitaminae. It is cultivated for its underground rhizomes which is used as spice, condiment and dye stuff. It is used in cosmetic and drug industry, particularly in the preparation of anticancerous medicines. Globally, India is the world's largest producer and exporter of turmeric and produces nearly 50 per cent of global turmeric production. India is also the largest consumer of turmeric in the world accounting for nearly 90% of total production. Major producing states in India are Telangana, Andhra Pradesh, Tamil Nadu, Orissa, West Bengal, Karnataka and Kerala. In India tumeric is estimated to occupy an area of 295000 hectares with a production of 1102000 MT (Horticultural statistics Database: 2020-21). The area in Telangana under turmeric cultivation is 55443 hectares with production of 307000 MT ha-1 and Productivity is 5.5 t ha-1. It is also used in the auspicious rituals and religious occasions. Turmeric inhibits the development of cataracts, breast cancer, colon cancer, and lymphoma (Devi and Sangamithra, 2011) [5]. Turmeric being a long duration (8-9 months) exhaustive crop responds well to nutrition. Hence, optimum dose of nutrients is essential to get good yield. Use of chemical fertilizer, herbicide and pesticide in horticulture for increasing yield and controlling weeds and pests will contaminate the water, air, food, decrease soil fertility, inhibit growth of soil microorganisms and hazard human health.

This negative effect of agricultural practices could be reversed by the correct utilization of manures and/ or crop residues within cropping system either alone or in combination with organic fertilizer (Mandal *et al.* 2007) [15]. Beside these, utilization of organic manure is recommended for retaining productivity of problem soils, reducing the usages of chemical fertilizer, improving economy and minimizing environmental problems.

Material and methods

The present investigation was conducted at College of Horticulture, Rajendranagar during 2018-19. The experiment was laid out in Factorial randomized block design (FRBD) with 18 treatments and 2 replications. The treatments used in this experiment are as follows:

Factor – I: Organic manures and biofertilizers

M_1: FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_2: Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_3: Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost
M_4: Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake
M_5: Control (RDF - 150: 60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l q^{-1}
M_6: Control (RDF - 150: 60: 108 NPK kg ha^{-1})

Factor – II: Varieties (V)

V_1: First best treatment of first experiment (Vertical split of mother rhizome) Salem (Long duration)
V_2: First best treatment of first experiment (Vertical split of mother rhizome) Rajendra Sonia (Medium duration)
V_3: First best treatment of first experiment (Vertical split of mother rhizome) ACC – 79 (Short duration)

Treatment combinations

M_1V_1: FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome of Salem)
M_1V_2: FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome of Rajendra Soina)
M_1V_3: FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizomeof ACC – 79)
M_2V_1: Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome of Salem)
M_2V_2: Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome of Rajendra Sonia)
M_2V_3: Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome of ACC – 79)
M_3V_1: Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome of Salem)
M_3V_2: Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome of Rajendra Sonia)
M_3V_3: Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome of ACC – 79)
M_4V_1: Neemcake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake + First best treatment of first experiment (Vertical split of mother rhizome of Salem)
M_4V_2: Neemcake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake + First best treatment of first experiment (Vertical split of mother rhizome of Rajendra Sonia)
M_4V_3: Neemcake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake + First best treatment of first experiment (Vertical split of mother rhizome of ACC – 79)
M_5V_1: Control (RDF- 150: 60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l ha-1 + First best treatment of first experiment (Vertical split of mother rhizome of Salem)
M_5V_2: Control (RDF- 150: 60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l ha^{-1}+ First best treatment of first experiment (Vertical split of mother rhizome of Rajendra Sonia)
M_5V_3: Control (RDF- 150: 60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l ha^{-1}+ First best treatment of first experiment (Vertical split of mother rhizome of ACC – 79)
M_6V_1: Control (RDF- 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome of Salem)
M_6V_2: Control (RDF - 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome of Rajendra Sonia)
M_6V_3: Control (RDF - 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome of ACC – 79).

Results and Discussion

The results of the present investigation regarding the response of organic manures, biofertilizers, varieties and their combinations on growth, yield and economics of Turmeric have been discussed and interpreted in light of previous research work in India. The results of the experiment are summarized below and also presented in table 1, 2, 3 and 4 and also depicted in the graph fig.1.

1. Plant height (cm)

Effect of organic manures and biofertilizers on plant height of Turmeric

At harvest, there were significant differences among organic treatments and biofertilizers. The treatment M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost recorded significantly maximum plant height (64.40 cm) followed by M_4 - Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake (63.05 cm). The treatment M_6 - Control (RDF - 150: 60: 108 NPK kg ha^{-1}) reported significantly minimum plant height (51.30 cm).

Effect of varieties on plant height of turmeric

At harvest, varieties had significant effect on plant height. The variety V_1 – First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety reported significantly maximum plant height (67.70 cm) followed by variety V_2 – First best treatment of first (Vertical split of mother rhizome) of Rajendra Sonia variety (53.22 cm). The

variety V_3- First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 variety reported significantly minimum plant height (49.12 cm).

Interaction effect of organic manures, biofertilizers and varieties on plant height

At harvest, interaction between organic manures, biofertilizers and varieties reported significant effect on plant height. The treatment M_3V_1 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum plant height (79.47 cm) followed by M_4V_1 –Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (71.19 cm) and M_1V_1 – FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (67.85 cm). The treatment M_6V_3 – Control (RDF- 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 variety recorded significantly minimum plant height (42.91 cm).

Kale *et al*. (1992) [10] observed that vermicompost application enhanced the activity of beneficial microbes like N_2 fixers and colonization by mycorrhizal fungi and hence play a significant role in N_2 fixation and phosphate mobilization leading to better uptake by the plant. Thus the increased availability of nutrients and uptake by the plants would have resulted in better performance of growth parameters in plots treated with vermicompost. Use of FYM increases soil organic matter content and this has a greater residual effect (Kumaran *et al.* 1998) [14]. Application of different combinations of organic manures like FYM, neemcake, vermicompost also influence the growth of turmeric (Sarma, 2015) [26].

2. Number of tillers per plant

Effect of organic manures and biofertilizers on number of tillers per plant

At harvest, there were significant differences among organic treatments and biofertilizers. The treatment M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost recorded significantly maximum number of tillers per plant (5.48) followed by M_4 - Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake (5.32) and M_1 - FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure (5.07) which were found to be on par. The treatment M_6 - Control (RDF - 150: 60: 108 NPK kg ha^{-1}) recorded significantly minimum number of tillers per plant (4.18).

Effect of varieties on number of tillers per plant

At harvest, varieties recorded significant effect on number of tillers per plants. The variety V_1 – First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety reported significantly maximum number of tillers per plant (5.20) followed by variety V_2 – First best treatment of first experiment (Vertical split of mother rhizome) of Rajendra Sonia variety (5.03). The variety V_3- First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 variety reported significantly minimum number of tillers per plant (4.44).

Interaction effect of organic manures, biofertilizers and varieties on number of tillers per plant

At harvest, interaction between organic manures, biofertilizers and varieties recorded significant effect on number of tillers per plant. The treatment M_3V_1 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum number of tillers per plant (6.12) followed by M_4V_1 –Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (5.72). M_1V_1 – FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (5.22) and M_2V_1 – Poultry manure 7 t ha^{-1} + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (5.15) were on par. The treatment M_6V_1 – Control (RDF- 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly minimum number of tillers per plant (3.69).

The number of tillers is an important yield attribute in turmeric, which would influence the yield and mother rhizome development in turmeric as reported by Balkrishnamurthy *et al* (2009) [2] in turmeric. The results are also in confirmation with findings of Singh *et al* (2009) [28] in ginger and Singh, 2013 in turmeric.

The vegetative growth in turmeric was obtained by application of organic manures may be due to an increase in the activity of enzymes like chitinases and proteases which break down the organic-rich compounds. The activities of microflora and microfauna population in the soil is increased which inturn increases the availability of macro and micronutrients especially by application of vermicompost, FYM, organic and inorganic fertilizers (Kumar *et al*. 2018) [12]. These results are in conformity with Poapst *et al*. 1970 [22], who reported that earthworm's cast shows hormone-like activity and stimulates plant nutrient uptake and the metabolism resulted in an increase in plant growth. The vegetative growth of the turmeric was influenced by use of various organic manures (FYM and Vermicompost) and revealed increase in crop yield as well as improvement in the physical, chemical and biological properties of soil (Dudhat *et al*., 1997) [6].

3. Leaf area (cm^2)

Effect of organic manures and biofertilizers on leaf area

At harvest, there were significant differences among organic treatments and biofertilizers on leaf area. The treatment M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost recorded significantly maximum leaf area (404.91 cm^2) followed by M_4 - Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake (382.27 cm^2) which were at par. The treatment M_6 - Control (RDF – 150: 60: 108 NPK kg ha^{-1}) recorded significantly minimum leaf area (274.69 cm^2).

Effect of varieties on leaf area

At harvest, varieties had significant effect on leaf area. The variety V_1 – First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety reported significantly maximum leaf area (524.02 cm^2) followed by

variety V_2- First best treatment of first experiment (Vertical split of mother rhizome) of Rajendra Sonia variety (323.58 cm^2). The variety V_3- First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 variety reported significantly minimum leaf area (171.35 cm^2).

Interaction effect of organic manures, biofertilizers and varieties on leaf area

At harvest, interaction between organic manures, biofertilizers and varieties recorded significant effect on leaf area. The treatment M_3V_1 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum leaf area (576.41 cm^2) followed by M_4V_1 –Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (567.04 cm^2). The treatment M_6V_3 – Control (RDF-150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 variety recorded significantly minimum leaf area (117.44 cm^2).

Incorporation of organic manures and biofertilizers improved the soil physical, chemical, and biological properties which in turn improves the water and nutrient availability, organic matter content and consequently increasing the plant growth parameters (AlFraihat, 2011) [11]. The beneficial effect of organic manures on growth characters might be due to additional supply of nutrients as well as improvement in physic-chemical properties of soil. These findings are in good agreement with those of Kumar *et al*. (2018) [13].

4. Fresh weight of rhizomes per clump (g)

Effect of organic manures and biofertilizers on fresh weight of rhizomes per clump

At harvest, fresh weight of rhizomes per clump was significantly affected by organic manures and biofertilizers. Among all the organic manures and biofertilizers, the treatment M_1 – FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure recorded significantly maximum fresh weight of rhizomes per clump (409.53 g) followed by M_3 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost (320.13 g) and M_4 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake (305.18 g). The treatment M_6 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) recorded significantly minimum fresh weight of rhizomes per clump (206.23 g).

Effect of varieties on fresh weight of rhizomes per clump

Among varieties, fresh weight of rhizomes per clump was significantly affected at harvest. The variety V_1- First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum fresh weight of rhizomes per clump (482.34 g) followed by V_2 – First best treatment of first experiment (Vertical split of mother rhizome) of Rajendra Sonia variety (240.59 g). Whereas minimum fresh weight of rhizomes per clump was recorded by variety V_3- First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 (151.77 g).

Interaction effect of organic manures, biofertilizers and varieties on fresh weight of rhizomes per clump

Interaction between organic treatments and spacing had significant effect on fresh weight of rhizomes per clump at harvest. Among all interactions, M_1V_1 –FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum fresh weight of rhizomes per clump (756.10 g) followed by M_3V_1 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best variety of first experiment (Vertical split of mother rhizome) of Salem variety (508.10 g), M_4V_1 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (506.05 g) and M_2V_1 – Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best variety of first experiment (Vertical split of mother rhizome) of Salem variety (480.10 g). The treatment M_6V_3 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) of ACC -79 variety (114.20 g) reported significantly minimum fresh weight of rhizomes per clump.

The combined application of organic manures and biofertilizers (AMC) might have supplied adequate amounts of nutrients, which favoured higher metabolic rate and Auxin activities in the plant, resulting in better yield attributes and higher seed yield. This is in accordance with the findings of Manohar *et al*. (2012) [17] in Ashwagandha. The availability of the major nutrients which are actively involved in vital processes was enhanced by application of organic manures and biofertilizer inoculations which ultimately resulted in higher yield. The results are in concurrence with findings of Panchabhai *et al*., 2005 [21] and Yadav *et al*., 2013 [31] in Ashwagandha. Organic manures improved the soil productivity and fertility which in turns improved yield of such long duration crop like turmeric. In this experiment, application of higher dose of farmyard manure (FYM) and vermicompost increased the growth, dry matter accumulation, and ultimately the yield of turmeric. Similar findings were reported by Hossain and Ishimine (2007) [9], Manhass and Gill (2010) [16], Mohapatra and Das (2009) [18] in Turmeric.

5. Dry weight of rhizomes per clump (g)

Effect of organic manures and biofertilizers on dry weight of rhizomes per clump

At harvest, dry weight of rhizomes per clump was significantly affected by organic manures and biofertilizers. Among all the organic manures and biofertilizers, the treatment M_1 – FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure recorded significantly maximum dry weight of rhizomes per clump (82.2 g) followed by M_3 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost (60.73 g) and M_4 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake (58.56 g). The treatment M_6 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) reported significantly minimum dry weight of rhizomes per clump (45.63 g).

Effect of varieties on dry weight of rhizomes per clump

Among varieties, dry weight of rhizomes per clump was significantly affected at harvest. The variety V_1- First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum dry weight of rhizomes per clump (88.92 g) followed by V_2 – First best treatment of first experiment (Vertical split of

mother rhizome) of Rajendra Sonia variety (49.32 g). Whereas minimum dry weight of rhizomes per clump was recorded by variety V_3- First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 (36.59 g).

Interaction effect of organic manures, biofertilizers and varieties on dry weight of rhizomes per clump

Interaction between organic treatments and spacing had significant effect on dry weight of rhizomes per clump at harvest. Among all interactions, M_1V_1 –FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum dry weight of rhizomes per clump (148.15 g) followed by M_3V_1 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best variety of first experiment (Vertical split of mother rhizome) of Salem variety (92.20 g) and M_4V_1 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (91.20 g). The treatment M_6V_3 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) of ACC -79 variety (35.30 g) reported significantly minimum dry weight of rhizomes per clump.

The addition of organic manures along with biofertilizer combination would have resulted in higher stimulating effect on increased nutrient uptake resulting in greater dry weight of rhizomes. The present investigation is in concurrence with earlier findings of Reddy and Rao (1978) [23], Rao and Rao (1988) and Velmurugan (2002) in turmeric.

Organic manures improved soil productivity and fertility which in turns improved yield of such long duration crop like turmeric. Application of higher dose of farmyard manure (FYM) and vermicompost increased the growth, dry matter accumulation and yield of turmeric. The results are in confirmity with the findings of Hossain and Ishimine (2007) [9], Manhass and Gill (2010) [16], Mohapatra and Das (2009) [18] in turmeric.

Datta *et al*. (2017) [4] reported that Maximum dry recovery (27.22%) was recorded in the treatment of sole application of FYM @ 15 tonnes/ha. Higher production of dry matter by the plant and was reported with application of organic manures and biofertilizers which might be due to the fact that organic manures have high amounts of humus, which facilitate N-fixation by microbes, regulate the nitrogen supply to the plants and also helps in the production of plant growth promoters (Krishnamoorthy and Ravikumar, 1973) [11] in mint.

6. Rhizome yield per plant (g)

Effect of organic manures and biofertilizers on rhizome yield per plant

At harvest, rhizome yield per plant was significantly affected by organic manures and biofertilizers. Among all the organic manures and biofertilizers, the treatment M_1 – FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure recorded significantly maximum rhizome yield per plant (486.98 g) followed by M_3 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost (453.69 g) and M_4 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake (404.03 g). The treatment M_6 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) reported significantly minimum rhizome yield per plant (283.65 g).

Effect of varieties on rhizome yield per plant

Among varieties, rhizome yield per plant was significantly affected at harvest. The variety V_1- First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum rhizome yield per plant (670.65 g) followed by V_2 – First best treatment of first experiment (Vertical split of mother rhizome) of Rajendra Sonia variety (288.50 g). Whereas minimum rhizome yield per plant was recorded by variety V_3-First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 (207.05 g).

Interaction effect of organic manures, biofertilizers and varieties on rhizome yield per plant

Interaction between organic treatments and spacing had significant effect on rhizome yield per plant at harvest. Among all interactions, M_1V_1 –FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety recorded significantly maximum rhizome yield per plant (890.40 g) followed by M_3V_1 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best variety of first experiment (Vertical split of mother rhizome) of Salem variety (810.33 g) and M_4V_1 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (710.33 g). The treatment M_6V_3 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) of ACC -79 (35.30 g) reported significantly minimum rhizome yield per plant.

By the use of various organic manures (FYM and Vermicompost) influenced vegetative growth of the turmeric which increased the crop yield as well as the physical, chemical and biological properties of soils (Dudhat *et al*. 1997) [6]. FYM has favourable effect on soil physical, chemical and biological factors that determine the productivity and fertility status of soil and supply nutrients in available form, resulting in higher crop yield and productivity. Similar studies of Brahmi in Assam conditions, by addition of organic manure resulted in faster spread and ground coverage of Brahmi and use of enriched compost @ 2 t ha^{-1} was determined as optimum (Baruah *et al*. 2014) [3].

7. Rhizome yield per plot (kg)

Effect of organic manures and biofertilizers on rhizome yield per plot

At harvest, rhizome yield per plot was significantly effected by organic manures and biofertilizers. Among all the organic manures and biofertilizers, the treatment M_1 – FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure recorded significantly maximum rhizome yield per plot (24.33 kg) followed by M_3 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost (22.66 kg) and M_4 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake (20.18 kg). The treatment M_6 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) reported significantly minimum rhizome yield per plot (14.16 kg).

Effect of varieties on rhizome yield per plot

Among varieties, rhizome yield per plot was significantly affected at harvest. The variety V_1- First best treatment of first experiment (Vertical split of mother rhizome) Salem recorded significantly maximum rhizome yield per plot (33.51 kg) followed by V_2 – First best treatment of first experiment (Vertical split of mother rhizome) Rajendra Sonia (14.40 kg). Whereas minimum rhizome yield per plot was recorded by variety V_3- First best treatment of first experiment (Vertical split of mother rhizome) ACC-79 (10.33 kg).

Interaction effect of organic manures, biofertilizers and varieties on rhizome yield per plot

Interaction between organic treatments and spacing had significant effect on rhizome yield per plot at harvest. Among all interactions, M_1V_1 –FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) Salem recorded significantly maximum rhizome yield per plot (44.50 kg) followed by M_3V_1 – Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure + First best variety of first experiment (Vertical split of mother rhizome) Salem (40.50 kg) and M_4V_1 – Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} neem cake + First best treatment of first experiment (Vertical split of mother rhizome) Salem (35.50 kg). The treatment M_6V_3 – Control (RDF – 150: 60: 108 NPK kg ha^{-1}) + First best treatment of first experiment (Vertical split of mother rhizome) ACC -79 (7.50 kg) reported significantly minimum rhizome yield per plot.

Humus substances present in FYM could have mobilised the reserve food materials from source to the sink through increased activity of hydrolysing and oxidising enzymes. This combined application would help for the better availability and utilization of nutrients. This is in consonance with earlier findings of Sugito and Maftuchah (1995) [30] and Gill *et al.* (1999) [7] in turmeric. All these scavenging effects might have made quick mobilization and availability of nutrients which would have aided in greater fresh weight of all types of rhizomes. All these factors ultimately resulted in higher yields in this particular treatment. This is in confirmation with findings of Mato and Mendez (1970) [19]. In addition to this, FYM is a good source of carbon and nitrogen, which are essential for the luxuriant growth and proliferation of soil microflora (Mosse, 1972) [20]. The beneficial effects of these microflora could have been expressed in the form of increased nutrient availability to the plants that might have ultimately reflected on increased yield of rhizomes. Similar line of work in ginger was documented by Sadanandhan and Hamza (1998) [25].

8. Benefit cost ratio

Significantly the highest benefit to cost ratio (3.68) was recorded in M_1V_1- FYM 45t ha^{-1} + AMC 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety followed by M_3V_1 - Vermicompost 14t ha^{-1} + AMC 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) of Salem variety (3.14). Significantly lesser benefit to cost ratio (-0.03) was recorded in the treatment M_6V_3 - Control (RDF – 150: 60: 108 NPK kg ha^{-1} + First best treatment of first experiment (Vertical split of mother rhizome) of ACC-79 variety.

The highest B: C ratio was recorded with the application of M_1V_1 - FYM 45t ha^{-1} + AMC 1 l q^{-1} manure + First best treatment of first experiment (Vertical split of mother rhizome) Salem. The probable reason might be being farmer friendly gives higher yield and it is economic to apply more.

From the above findings, it is concluded that the application of different combinations of FYM along with biofertilizer play a significant role in enhancing the soil fertility in terms of macronutrients, secondary nutrients, micronutrients and microbial population. The biofertilizers like Azospirillum, *Pseudomonas striata* and K-mobilizer (Arka microbial consortium) helped in enriching the soil with the major nutrients like N, P and K which are mainly essential for luxuriant growth of the crop. Similar results were reported by Sindhu *et al.* (2016) [27] in indigofera crop.

Table 1: Effect of organic manures, biofertilizers and varieties on plant height (cm), number of tillers per plant and leaf area (cm^2) of turmeric at harvest

Treatments	At harvest											
	Varieties (V)											
Organic manures and Bio-fertilizers (M)	Plant height (cm)				Number of tillers per plant				Leaf area (cm^2)			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean	V_1	V_2	V_3	MEAN
M_1	67.85	52.45	48.09	56.13	5.22	5.00	4.99	5.07	561.76	322.41	170.16	351.44
M_2	66.47	44.23	47.05	52.58	5.15	4.96	3.97	4.69	508.45	320.15	170.14	332.91
M_3	79.47	61.24	52.48	64.40	6.12	5.23	5.10	5.48	576.41	394.16	244.16	404.91
M_4	71.19	59.23	58.73	63.05	5.72	5.21	5.02	5.32	567.04	381.34	198.44	382.27
M_5	60.89	51.50	45.47	52.62	5.00	4.89	3.86	4.58	478.76	268.48	127.75	291.66
M_6	60.33	50.67	42.91	51.30	4.00	4.86	3.69	4.18	451.69	254.94	117.44	274.69
Mean	67.70	53.22	49.12		5.20	5.03	4.44		524.02	323.58	171.35	
	M	V	M x V		M	V	M x V		M	V	M x V	
S.Em±	0.23	0.16	0.39		0.11	0.08	0.19		2.05	1.45	3.55	
C.D (p =0.05)	0.69	0.48	1.19		0.33	0.23	N.S		6.12	4.32	10.61	

Factor -I: Organic manures and Biofertilizers

M_1 - FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_2 - Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost
M_4 - Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake
M_5 - Control (RDF - 150:60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l ha^{-1}
M_6 - Control (RDF - 150: 60: 108 NPK kg ha^{-1})

Factor -II: Varieties

V_1- First best treatment of first experiment (vertical split of mother rhizome) Salem
V_2 – First best treatment of first experiment (vertical split of mother rhizome) Rajendra Sonia
V_3 – First best treatment of first experiment (vertical split of mother rhizome) ACC-79

Table 2: Effect of organic manures, biofertilizers and varieties on fresh weight of rhizomes per clump and dry weight of rhizomes per clump of turmeric at harvest

Treatments	At harvest							
	Varieties (V)							
Organic manures and Bio-fertilizers (M)	Fresh weight of rhizomes per clump (g)				Dry weight of rhizomes per clump (g)			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
M_1	756.10	300.35	172.15	409.53	148.15	60.25	38.20	82.20
M_2	480.10	223.30	146.60	283.33	76.30	48.25	36.15	53.56
M_3	508.10	282.20	170.10	320.13	92.20	52.25	37.75	60.73
M_4	506.05	241.30	168.20	305.18	91.20	48.25	36.25	58.56
M_5	323.30	212.30	139.42	225.00	63.30	47.75	35.90	48.98
M_6	320.40	184.10	114.20	206.23	62.40	39.20	35.30	45.63
Mean	482.34	240.59	151.77		88.92	49.32	36.59	
	M	V	M x V		M	V	M x V	
S.Em±	2.74	1.79	4.53		0.45	0.29	0.74	
C.D (p =0.05)	7.85	5.37	13.59		1.35	0.87	2.22	

Factor -I: Organic manures and Biofertilizers
M_1 - FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_2 - Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost
M_4 - Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake
M_5 - Control (RDF - 150: 60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l ha^{-1}
M_6 - Control (RDF - 150: 60: 108 NPK kg ha^{-1})

Factor -II: Varieties
V_1- First best treatment of first experiment (vertical split of mother rhizome) Salem
V_2 – First best treatment of first experiment (vertical split of mother rhizome) Rajendra Sonia
V_3 – First best treatment of first experiment (vertical split of mother rhizome) ACC-79

Table 3: Effect of organic manures, biofertilizers and varieties on rhizome yield per plant and rhizome yield per plot of turmeric at harvest

Treatments	At harvest							
	Varieties (V)							
Organic manures and Bio-fertilizers (M)	Rhizome yield per plot (g)				Rhizome yield per plot (kg)			
	V_1	V_2	V_3	Mean	V_1	V_2	V_3	Mean
M_1	890.40	320.25	250.30	486.98	44.50	16.00	12.50	24.33
M_2	602.25	298.40	200.50	367.05	30.10	14.90	10.00	18.33
M_3	810.33	310.25	240.50	453.69	40.50	15.50	12.00	22.66
M_4	710.30	301.30	200.50	404.03	35.50	15.05	10.00	20.18
M_5	560.25	250.40	200.35	337.00	28.00	12.50	10.00	16.83
M_6	450.40	250.40	150.15	283.65	22.50	12.50	7.50	14.16
Mean	670.65	288.50	207.05		33.51	14.40	10.33	
	M	V	M x V		M	V	M x V	
S.Em±	1.56	0.99	2.55		0.67	0.43	1.10	
C.D (p =0.05)	4.68	2.97	7.65		2.01	1.29	3.30	

Factor -I: Organic manures and Biofertilizers
M_1 - FYM 45 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_2 - Poultry manure 7 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} manure
M_3 - Vermicompost 14 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} compost
M_4 - Neem cake 4.5 t ha^{-1} + AMC (Arka microbial consortium) 1 l q^{-1} Neem cake
M_5 - Control (RDF - 150: 60: 108 NPK kg ha^{-1}) + AMC (Arka microbial consortium) 1 l ha^{-1}
M_6 - Control (RDF - 150: 60: 108 NPK kg ha

Factor -II: Varieties
V_1- First best treatment of first experiment (vertical split of mother rhizome) Salem
V_2 – First best treatment of first experiment (vertical split of mother rhizome) Rajendra Sonia
V_3 – First best treatment of first experiment (vertical split of mother rhizome) ACC-79

Table. 4 Benefit cost ratio of turmeric effected by organic manures, biofertilizers and varieties

	Qty.	Rate Rs/t	Amt Rs.	Fixed cost Rs.	Total cost Rs.	Rhizome yield t ha^{-1}	Gross return Rs.	Net return Rs.	B:C Ratio
M_1V_1	FYM 45t/ha + AMC 1 lit per q manure + First best treatment of first experiment – Salem	1000 + 175	60750	931000	991750	48.88	4643600	3651850	3.68
M_1V_2	FYM 45t/ha +AMC 1 lit per q manure + First best treatment o first experiment – Rajendra Sonia	1000 + 175	60750	931000	991750	17.77	1688150	696400	0.70
M_1V_3	FYM 45t/ha +AMC 1 lit per q manure + First best treatment of first experiment – ACC-79	1000 + 175	60750	931000	991750	13.88	1318600	326850	0.32
M_2V1	Poultry manure 7t/ha +AMC 1 lit per q manure + First best treatment of first experiment – Salem	2000 + 175	29750	931000	960750	33.44	3176800	2216050	2.31
M_2V_2	Poultry manure 7t/ha +AMC 1 lit per q manure + First best treatment of first experiment – Rajendra Sonia	2000 + 175	29750	931000	960750	16.55	1572250	611500	0.63
M_2V_3	Poultry manure 7t/ha +AMC 1 lit per q manure + First best treatment of first experiment – ACC -79	2000 + 175	29750	931000	960750	11.11	1055450	94700	0.09
M_3V_1	Vermicompost 14t/ha +AMC 1 lit per q compost + First best treatment of first experiment – Salem	6000 + 175	99750	931000	1030750	45.00	4275000	3244250	3.14
M_3V_2	Vermicompost 14t/ha +AMC 1 lit per q compost + First best treatment of first experiment – Rajendra Sonia	6000 + 175	99750	931000	1030750	17.22	1635900	605150	0.58
M_3V_3	Vermicompost 14t/ha +AMC 1 lit per q compost + First best treatment of first experiment – ACC -79	6000 + 175	99750	931000	1030750	13.33	1266350	235600	0.22
M_4V_1	Neem cake 4.5 t/ha +AMC 1 lit per q Neem cake + First	15000 +	83250	931000	1014250	39.44	3746800	2732550	2.69

	best treatment of first experiment – Salem	175							
M_4V_2	Neem cake 4.5 t/ha +AMC 1 lit per q Neem cake + First best treatment of first experiment – Rajendra Sonia	15000 + 175	83250	931000	1014250	16.72	1588400	574150	0.57
M_4V_3	Neem cake 4.5 t/ha +AMC 1 lit per q Neem cake + First best treatment of first experiment – ACC-79	15000 + 175	83250	931000	1014250	11.11	1055450	41200	0.04
M_5V_1	Control (RDF – 150: 60: 108 NPK kg/ha) +AMC 1 lit/ha + First best treatment of first experiment – Salem	51 + 175	5425	931000	936425	31.11	2177700	1241275	1.32
M_5V_2	Control (RDF – 150: 60: 108 NPK kg/ha) + AMC 1 lit/ha + First best treatment of first experiment – Rajendra Sonia	51 + 175	5425	931000	936425	13.88	971600	875175	0.93
M_5V_3	Control (RDF – 150: 60: 108 NPK kg/ha) + AMC 1 lit/ha + First best treatment of first experiment – ACC - 79	51 + 175	5425	931000	936425	11.11	777700	-158725	- 0.16
M_6V_1	Control (RDF – 150: 60: 108 NPK kg/ha + First best treatment of first experiment – Salem	51	5250	931000	936250	25.00	2000000	1063750	1.13
M_6V_2	Control (RDF – 150: 60: 108 NPK kg/ha + First best treatment of first experiment – Rajendra Sonia	51	5250	931000	936250	13.88	1110400	174150	0.18
M_6V_3	Control (RDF – 150: 60: 108 NPK kg/ha + First best treatment of first experiment – ACC-79	51	5250	931000	936250	8.33	666400	- 26950	-0.03

Per tonne cost of dry rhizome – for organic turmeric – Rs. 95000 /-, for inorganic turmeric – Rs. 70000/-, for inorganic (inorganic treatments + AMC) turmeric - Rs.80000/-

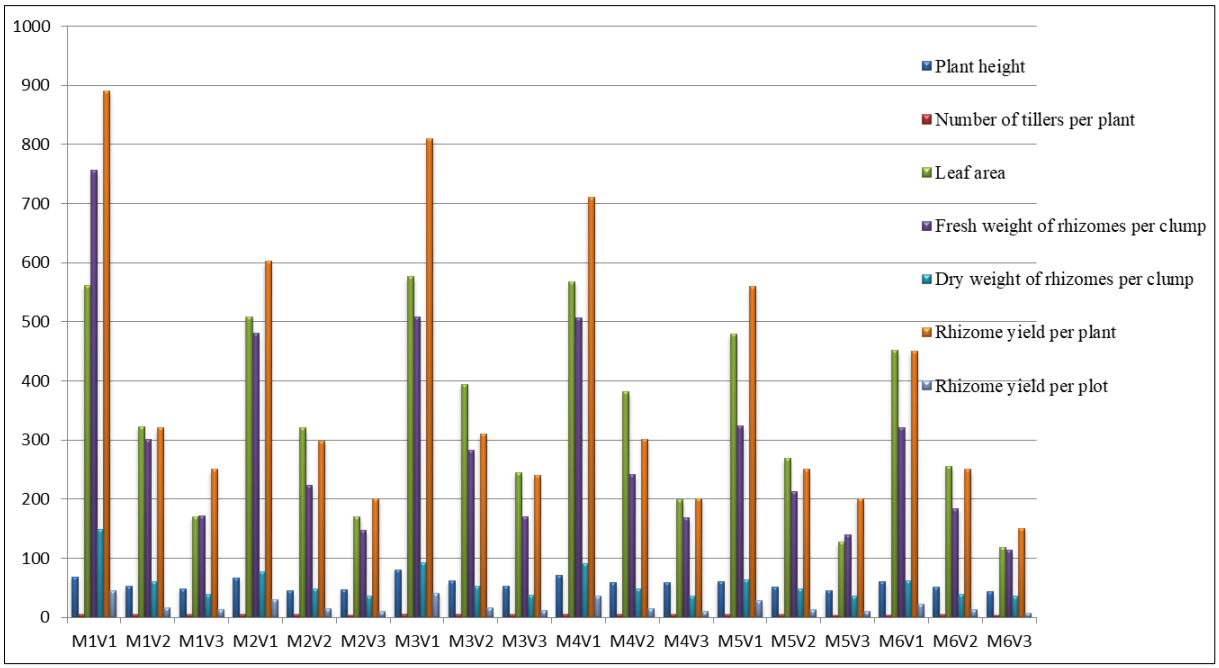

Fig 1. Effect of organic manures and biofertilizers on growth, yield and economics of Turmeric (*Curcuma longa* L.) varieties

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