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Effect of organic nutrient management and organic formulations on yield and biochemical-quality parameters of turmeric

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Abstract
Turmeric (*Curcuma longa* L.) is an important spice, medicinal and valued for its curcumin-rich rhizomes. This review synthesizes findings from national and international studies on the effects of organic manures and organic formulations on yield, yield attributes, and quality parameters of turmeric. Results consistently indicate that organic manures such as farmyard manure, vermicompost, poultry manure, neem cake, and oil cakes significantly enhance rhizome development, and fresh and cured rhizome yield compared to control treatments. Quality parameters including curcumin content, essential oil, oleoresin, curing percentage, and nutritional composition were also positively influenced by organic nutrient sources. Organic formulations such as jeevamrut, panchagavya, vermiwash, effective microorganisms, cow urine, and humic acid enhanced soil biological activity, crop growth, yield, and biochemical quality in turmeric and related crops. Integrated use of organic manures with organic formulations further improves nutrient availability, microbial activity, and yield performance. Overall, the reviewed studies demonstrate that organic nutrient management and organic formulations play a crucial role in improving turmeric productivity, quality, and soil health. Their adoption is essential for achieving environmentally sustainable, economically viable, and high-quality turmeric production.

Keywords: Agronomy of turmeric, review, yield, quality and biochemical parameters, organic nutrient management, organic formulations, etc.

Introduction

Turmeric (*Curcuma longa* L.) is an herbaceous perennial belonging to the family Zingiberaceae, originating from Southeast Asia and widely cultivated in tropical and subtropical regions. It is one of India's most important ancient spices and a traditional export commodity, used extensively as a spice, condiment, and in medicinal preparations. Commonly known as "Indian saffron," "yellow gold," and "the golden spice of life," India is the world's largest producer, consumer, and exporter of turmeric, with Indian turmeric valued for its high curcumin content (Devi and Sanghamitra, 2011) [18]. The crop is grown for its underground rhizomes and thrives under tropical conditions up to 900 m altitude, at 18-28 °C, with about 1500 mm annual rainfall. It performs best in well-drained sandy loam soils with a pH of 6.5-7.5.

Turmeric being a long duration (8-9 month) exhaustive crop responds well to nutrition, so optimum dose of nutrients is very much essential to produce good yield. The organic manure gives better quality produce as compared to those grown with inorganic sources of fertilizer. (Abusaleha and Shanmugavelu, 1985) [2]. They are superior with respect to desirable ingredients such as minerals, vitamin (B_1, B_2 and C), carbohydrate, protein and free amino acid as well as organic acids (Woese *et al.*,1997) [79]. Considering the worlds demand for organic food, soil health, productivity and the availability of local resources, it becomes essential to encourage the farmer to take the advantage of the international demand for organically produced spice, aromatic and medicinal products. Use of organic manure for crop production is gaining momentum as the organically produce products get high economic return and they are environmentally safe compared with inorganic fertilizers. Moreover, organic manures have beneficial effects on soil health and productivity.

The production of turmeric in India accounts for a major share of the total world production, making the country the largest producer, consumer, and exporter of turmeric globally. India not only dominates global turmeric supply but also plays a key role in meeting international demand. Other important turmeric-producing countries include China, Myanmar, Bangladesh, Indonesia, Sri Lanka, and Thailand. Among these, India consistently occupies the top position in terms of area and production. Major turmeric-growing states in India include Telangana, Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka, Odisha, West Bengal, Gujarat, Assam, Meghalaya, and Kerala. Turmeric produced in India is marketed both domestically and internationally in fresh, dried, and processed forms, catering to culinary, medicinal, cosmetic, and industrial uses (Anonymous, 2025) [5].

Application of organic manures improves soil properties by increasing plant-available nutrients, water-holding capacity, and cation exchange capacity, while reducing bulk density and enhancing beneficial microbial activity. Use of manures such as farmyard manure (FYM), vermicompost, and poultry manure is an effective practice for improving crop yields and sustaining soil fertility (Nanjappa *et al.*, 2001) [40]. FYM supplies essential macro- and micronutrients and improves the physical, chemical, and biological soil environment, thereby enhancing crop growth (Sangashetty and Babalad, 2011) [57]. Vermicompost, rich in humus-forming and nitrogen-fixing microorganisms, improves soil structure and nutrient availability, particularly phosphorus and potassium, which promotes better plant growth (Sudhakar *et al.*, 2002) [69]. Poultry manure, abundantly available from poultry industries, is a rich source of nitrogen and, when composted, releases nutrients steadily over time, ensuring efficient nutrient use with minimal losses (Amanullah *et al.*, 2006) [4]. Neem cake is an organic manure that improves soil health without harming plants or soil organisms. It supplies natural NPK and micronutrients, reduces soil alkalinity, enhances soil structure, water-holding capacity, and supports beneficial rhizosphere microflora, thereby promoting better root growth (Gupta, 2022) [23].

Traditional organic formulations are increasingly used to restore soil fertility and productivity by improving soil microflora, nutrient availability, salinity balance, and pH (Shivsubramanian & Ganeshkumar, 2004; Scheuerell & Mahaffee, 2002) [5, 60]. Soil enzymes play a key role in soil ecology, nutrient cycling, and organic matter decomposition, and their activity is enhanced under organic management (Moeskops *et al.*, 2010) [39]. Soil microorganisms facilitate nutrient transformation and improve soil fertility (Yamawaki *et al.*, 2013) [80]. Fermented liquid organic manures, rich in beneficial microbes, nutrients, vitamins, amino acids, and growth-promoting substances, enhance soil microbial activity, leading to improved crop growth, yield, and quality (Palekar, 2006; Boraiah *et al.*, 2017) [45, 11].

Vermiwash supplies growth-promoting hormones, enzymes, beneficial microbes, and essential nutrients that enhance plant growth, quality, and yield (Shield and Earl, 1982) [64]. Jeevamrut is a liquid organic manure rich in natural carbon, nutrients, and microbial biomass, which enhances soil biological activity and nutrient availability (Devakumar *et al.*, 2008; Kumar *et al.*, 2021) [16, 32]. Effective Microorganisms (EM), developed by Higa, are a consortium of beneficial microbes that positively influence soil and crop environment (Higa and Parr, 1994) [24]. Cow urine (gomutra) is a nutrient-rich, natural input with antimicrobial and pest-repellent properties that supports sustainable agriculture (Devasena and Sangeetha, 2022) [17]. Humic acid, a key component of organic matter, improves nutrient efficiency and stimulates plant growth, serving as an effective supplement to fertilizers (Duary, 2020; Khaled and Fawy, 2011) [20, 31].

Organic farming uses nature as the best role model for agriculture and considers soil as living. Different organic manures influence differently in terms of yield and quality of turmeric. Considering the economic importance of turmeric and environmental problems caused by chemicals application, it is important to cultivate turmeric using organic fertilizer. Hence, it is the need of the hour to know the best source of organic manure and organic formulations which could help in increasing the yield and quality and need to encourage the good management practices which are environment friendly and ecologically balanced. These studies collectively highlight the crucial role of organic nutrient management and organic formulations in enhancing turmeric yield and quality. Hence, their adoption is essential for achieving sustainable turmeric cultivation with higher productivity and improved quality.

Materials and Methods

I) Collection of Data and Literature Reviews

To assess the effects of organic nutrient management and organic formulations on turmeric as part of agronomic management, an extensive review of published research was undertaken. Relevant review articles, research papers, and information sources related to the subject were collected from national and international literature. Priority was given to recent and updated studies. The findings and interpretations presented in this paper are synthesized from these earlier investigations. Literature support was obtained through the Department of Agronomy and the University Library at the Central Campus of Mahatma Phule Krishi Vidyapeeth, Rahuri, utilizing digital resources such as J-Gate, CeRA, and other library-supported databases.

II) Organization and Management of Literature Data

Literature was systematically searched and screened using major scientific databases including PubMed, Scopus, Elsevier, ScienceDirect, Springer, Web of Science, Google Scholar, ResearchGate, Academia, Semantic Scholar, Wiley Online Library, and other academic platforms. Reference management software such as EndNote, Zotero, and Mendeley was employed to organize citations, manage references, and ensure accurate documentation. The collected literature was critically analyzed, properly recorded, and systematically presented in this review.

Results and Discussions

I) Effect of organic nutrient management

a) Effect of organic nutrient management on yield parameters and yield of turmeric

Farmyard manure application significantly improved plant height, number and weight of mother, primary and secondary rhizomes and fresh rhizome yield of turmeric. Maximum fresh rhizome yield (210.1 and 143.3 q ha^{-1} in year 2000 and 2001 respectively) was obtained with the application of 60 t FYM ha^{-1} (Gill *et al.*, 2004). The treatment with FYM + zinc solubilizing bacteria showed higher turmeric rhizome yield increase of 21.6 per cent than the FYM alone treatment (9.1 per cent) than no manure (control). The dry rhizome yield, reflected the promising effect of Zn and Fe enriched coir pith or FYM, and Zn enriched coir pith or FYM at no manure while at NPK + FYM and NPK + FYM+ Zn solubilizing bacteria, the foliar spray of Zn + Fe + MOP excelled the remaining treatments (Senthilkumar *et al.*, 2004) [61]. The organic inputs *viz.*, FYM @ 12 t acre^{-1} + vermicompost 1 t acre^{-1} recorded the maximum weight of mother rhizome, primary rhizomes, secondary rhizomes, yield per plant and rhizome yield 48.8 t ha^{-1} against 19.53 t ha^{-1} in control (Rajamani *et al.*, 2007) [50]. Yield attributes like weight of mother rhizome, total fingers per plant, weight of primary and secondary fingers per plant and rhizome weight per plant were found highest with the application of FYM and poultry manure, which contributed to higher rhizome yield over the other treatments. Application of various organic sources resulted in 16 per cent higher rhizome yield over control (Sanwal *et al.*, 2007) [58]. The combined application of farmyard manure along with *azospirillum* + *phosphobacteria* + VAM (M_1S_7) recorded the supremacy for yield attributes like more number, length, girth and weight of mother, primary and secondary rhizomes. All these parameters contributed to yield per plant (0.838 kg) and the highest estimated yield (33313 kg ha^{-1}) (Velmurugan *et al.*, 2007) [77]. Vermicompost @ 25 t ha^{-1} and neem cake @ 6 t ha^{-1} were significantly superior to all other treatments and recorded maximum rhizome spread, rhizome thickness, root spread, root length, root weight and number of fingers. Vermicompost @ 25 t ha^{-1} was significantly superior and recorded maximum fresh rhizome yield of kasthuri turmeric. The same treatment resulted into yield of 364.95 g plant^{-1} and 396.33 g plant^{-1} during first and second year, respectively (Nirmalatha *et al.*, 2010) [42]. Different treatments significantly increased length of rhizome finger, diameter of rhizome finger and yield of fresh and cured ginger as compared to control. Combined application of 50% NPK + 50% pig manure recorded maximum fresh and cured yield, which were at par with 50% NPK + 50% FYM and 50% NPK + 50% vermicompost (Yanthan *et al*., 2010) [81]. A significant difference in the rhizome yield was noticed when organic manure-microbial inoculants combination was compared with recommended dose of fertilizers (inorganic). Among the different treatment combinations tried, the most effective treatment was vermicompost + *Azospirillum* + AM (28.94 t ha^{-1}), followed by compost + *Azospirillum* + AM (26.93 t ha^{-1}) as compared to recommended inorganic fertilizers (150:60:150 kg/NPK/ha) (24. t ha^{-1}) (Roy and Hore, 2011) [54]. Yield attributes such as number of mother rhizomes per plant (1.75), more number of primary rhizomes per plant (5.19), secondary rhizomes per plant (18.03) and tertiary rhizomes per plant (7.69) were also highly accelerated by neem cake application @ 2 t ha^{-1}. Similarly, the same treatment expressed the best in terms of size of mother rhizome (7.69 cm), primary rhizome (21.86 cm) and secondary rhizomes (7.05 cm). All these parameters in cumulative contributed to produce the highest estimated fresh rhizomes yield and cured rhizomes yield (29.48 t ha^{-1}, 5.59 t ha^{-1} respectively) (Kamal and Yousuf, 2012) [29]. Organic sources of nutrients, farm yard manure (FYM) @ 10 t ha^{-1} resulted in maximum growth and yield attributes. The maximum fresh yield of rhizomes was 103.81 q ha^{-1} over control (Pandey *et al.*, 2012) [46]. Maximum number of mother rhizomes per plant (2.78), number of fingers per rhizome (12.10), volume of rhizomes per plant (164.38 cc), weight of fresh rhizomes per plant (189.89 g), yield of fresh rhizomes per plot (5.700 kg) and yield of fresh rhizomes per hectare (40.25 t) followed by T_{15} (RD of N through poultry manure + RD of P and K + RD of Fe) and T_{14} (RD of N through poultry manure + RD of P and K + RD of Zn) (Patel *et al.*, 2012) [47]. Rhizomes and root characters followed by full dose of Neem cake 6.0 t ha^{-1}. Highest fresh and dry rhizome yield was produced by full dose of vermicompost 25.0 t ha^{-1} (Bhende *et al.*, 2013) [9]. Yield attributes such as number of mother rhizomes plant^{-1}, number of primary rhizomes plant^{-1}, secondary rhizomes plant^{-1} and tertiary rhizomes plant^{-1} were also highly accelerated by neem cake application. Similarly, the same treatment was expressed best in terms of size of mother rhizome, primary and secondary rhizomes. All these parameters cumulatively contributed to produce the highest estimated fresh rhizomes yield and cured rhizomes yield respectively. However, highest curing percentage (20.28) was observed in treatment having mustard cake@ 2.0 tonnes ha^{-1}. Thus, neem cake was best suited natural fertilizer for turmeric cultivation (Kumar *et al.*, 2013) [34]. Scientific practice (FYM @ 20 t ha^{-1} + Neem cake @ 0.1 t ha^{-1} + Organic plant protection) recorded significantly higher number of fingers hill^{-1} (12.21), rhizome yield (18.09 t ha^{-1}) and dry rhizome yield (4.69 t ha^{-1}) (Sahoo *et al.*, 2015) [56]. The highest rhizome yield (20.48 t ha^{-1}) was obtained in the treatment combined applications of FYM + vermicompost + neem cake and the lowest yield (12.50 t ha^{-1}) was obtained in the treatment of control (Sarma *et al.*, 2015) [59]. Yield attributes (*viz.*, weight of primary and secondary rhizomes per plant, fresh weight of rhizomes per plant, dry matter recovery (%), leaf area index, leaf area duration, dry leaves per plot, rhizomes yield per plot and per hectare) were found in the treatment of Poultry manure @ 5 t ha^{-1} as compared to control (Singh *et al*., 2015) [68]. vermicompost 7.5 t ha^{-1} @ + FYM 15 t ha^{-1} + *Azophos* @ 5 kg ha^{-1} resulted supremacy in growth and yield character over conventional nutrient management system. The same trend was observed for quality parameters too but was mainly influenced due to varietal differences (Basak and Jana, 2016) [7]. Application of FYM 15 t ha^{-1} + Vermicompost 3.8 t ha^{-1}+ Neem cake 1.5 t ha^{-1} (T_4) significantly higher fresh rhizome yield (606.54 g plant^{-1}), projected dry yield (7.6 t ha^{-1}) and curing (25.25%) (Kumar *et al.*, 2016) [33]. Highest rhizome yield was obtained from turmeric variety Lakdong with 100% organic treatment (11.1 t ha^{-1}). While two varieties, Lakdong and Phulbani Local exhibited highest yield with 100% organic treatment, performance of Rajendra Sonia was the best with 50% organic + 50% inorganic + lime @ 10% LR and Roma with 50% organic + 50% inorganic. Significant variation was observed among nutrient treatments of all four turmeric varieties for NPK content in shoot and rhizome (Mishra *et al.*, 2017) [38]. Application of organic manure (FYM) had beneficial effects on the growth, yield attributes and yield of turmeric. The maximum yield of 204.4 q ha^{-1} was obtained with application of 125 per cent of recommended organic manure combined with the bio-fertilizers, which was statistically at par with that of 100 per cent of recommended organic manure alone or in combination with the bio-fertilizers. Application of bio-fertilizers improved the growth and yield of turmeric to some extent (Singh *et al.*, 2017) [67]. Application of 75% NPK (Recommended Dose Fertilizer) + Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + Neem cake (500 kg ha^{-1}) + *Azotobacter* (2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}) (T_6)

enhanced the fresh rhizome yield (29.69 t ha^{-1}) whereas curing percentage (24%) (Amala *et al.*, 2019). Processed finger yield with application of Neem cake @ 4 t ha^{-1} + *Azotobacter* (10 kg ha^{-1}) + PSB (10 kg ha^{-1}) + VAM (65 kg ha^{-1}) found to be superior over other treatments (Bondre *et al*., 2019) [10]. The maximum dry rhizome yield (62.42 q ha^{-1}) was recorded in the application of a recommended dose of fertilizer to turmeric which was at par with the application of vermicompost (55.45 q ha^{-1}), however fresh rhizome yield was significantly (at 0.05 %) highest in the application of a recommended dose of fertilizer to turmeric (312.12 q ha^{-1}) which was followed by vermicompost (264.24 q ha^{-1}) (Kadam and Kamble, 2020) [28]. Application of 50% RDF + 50% NC resulted in significantly higher fresh weight of primary rhizome (46.5 g), fresh weight of secondary rhizome (55.5 g) and high marketable yield of rhizome (251.2 q ha^{-1}) over control. The total yield of fresh rhizome per plot was comparatively on higher side (418.5 g) when compared to control (308.1 g) and other treatments (Lohar and Hase, 2021) [36]. The length of rhizomes influenced the yield of turmeric so the application of biomanuring helpful for getting the maximum yield. The experimental results revealed that, application of 100% N through integration of organic manures as 50% Vermicompost + 50% Neemcake + Biofertilizers registered significantly the highest length (cm) of mother rhizome, primary rhizome and secondary rhizome than other treatments of nutrient management through bio-manuring in both year of experiment (Darekar *et al.,* 2022) [14].

b) Effect of organic nutrient management on biochemical-quality parameters of turmeric

Addition of FYM at the rate of 10 t ha^{-1} increased the curcumin content by 7 per cent over the control plot (Baghla, 2001) [6]. The volatile oil content 4.30% and curcumin content 4.87% were recorded with application of vermicompost alone (Rakhee, 2002) [51]. The quality characters, curcumin content was more (2.39%) with neem cake @ 1.25 t ha^{-1} + FYM @ 12.5 t ha^{-1} + RFD, whereas essential oils and oleoresins were more in vermicompost @ 1.0 t ha^{-1} alone (4.38% and 7.40%, respectively) over RFD (curcumin content 1.70%, essential oils 3.56% and oleoresins 5.82%) (Rao *et al.*, 2005) [52]. FYM incorporation at the rate of 15 t ha^{-1} alone improved the curcumin content in the turmeric rhizome by 6.8 per cent over the untreated plot (Dixit and Bhardwaj, 2006) [19]. Maximum curcumin (5.57%) and essential oil (5.68%) content recorded with the application of recommended dose of NPK + FYM @ 15 t ha^{-1} + coir compost @ 10 t ha^{-1} + *Azospirillium* @ 10 kg ha^{-1} + *Phosphobacteria* @ 10 kg ha^{-1} + Panchagavya @ 3 per cent. Higher curcumin content (6.76%) in plots treated with neem shield followed by bioplus and FYM (Sanwal *et al.*, 2007) [58]. The inoculation of phosphorus and AM fungi (*Scutellospora heterogama* and *Gigaspora decipiens*) yielded in maximum oleoresin content 3.48 and 1.58 per cent respectively (Silva *et al.*, 2008) [66]. The higher content of curcumin and oleoresin (4.577 and 9.477) was recorded under the application of farmyard manure + *Azospirillum* + *Phosphobacteria* + VAM. The highest essential content (3.817 per cent) was recorded under the application of vermicompost + *Azsopirillum* + *Phosphobacteria* +VAM (Velmurugan *et al*., 2008) [78]. Maximum curcumin content (6.71%) was recorded with compost + *Azospirillum* + AM followed by vermicompost + *Azospirillum* + AM (6.46%) as compared to the lowest curcumin (5.54%) with phosphocompost + AM. The rhizomes grown with vermicompost + *Azospirillum* + AM had the highest oleoresin content (11.10%) followed by compost + *Azospirillum* + AM (10.83%) (Roy and Hore, 2011) [54]. Highest curing percentage (20.28) in treatment having mustard cake @ 2.0 t ha^{-1}. In case of curcumin content, it was maximum (3.73%) in treatment fertilized with neem cake @ 2.0 t ha^{-1} but the treatment differences for curcumin content were non-significant (Kumar *et al.*, 2013) [34]. Application of vermicompost @ 5 t ha^{-1} + *Azospirillum* @ 5 kg ha^{-1} recorded maximum essential oil (4.94%) while lowest (2.11%) in control (Singh *et al.*, 2015) [68]. Application of FYM 15 t ha^{-1} + Vermicompost 3.8 t ha^{-1}+ Neem cake 1.5 t ha^{-1} (T_4) significantly higher curcumin (5.3%) and essential oil (4.2%) (Kumar *et al.*, 2016) [33]. The maximum dry recovery (27.22%) and curcumin content (5.24%) was recorded in the treatment of sole application of FYM @ 15 t ha^{-1} (T_1) **(**Datta *et al.*, 2017)**.** Higher curcumin content of 5.11% was recorded in organic nutrient management with *Azospirillum* at 5 kg ha^{-1} and FYM at 30 t ha^{-1}**.** The biochemical analysis showed that curcumin content, volatile oil, non-volatile ether extract (NVEE), crude fibre, starch, total carbohydrates and protein content were significantly influenced by the application of organic manures and vermicompost 25.0 t ha^{-1} was found to be superior to all other treatment (Nirmalata and Sulekha, 2019) [41]. The highest curcumin (5.19%) was recorded in the recommended dose of fertilizer to turmeric which was at par with an application of farm yard manure, vermicompost and press mud cake **(**Kadam and Kamble**,** 2020) [28]. Application FYM @ 10 t ha^{-1} + Microbial consortia as slurry T_7 exhibited best performance in terms of curing percentage (18.09%) and curcumin content (3.62%)**.** Application of 50 % RDF + 50 % NC proved superior for enhancing the quality parameters of turmeric such as fats (1.06%), protein (1.25%), carbohydrates (9.25%) and curcumin (5.13%) content to other treatments (Lohar and Hase, 2021) [36].

II) Effect of organic formulations

c) Effect of organic formulations on yield parameters and yield of turmeric

Combined application of beejamrutha + jeevamrut + panchagavya and increased dry fruit yield of chilli (8.52 and 8.01 q ha^{-1}, respectively) as compare to beejamrutha + jeevamrut application (Chandrakala *et al*., 2007) **(**Takar *et al.*, 2020) [12]. The liquid manures like beejamrutha, jeevamrut and panchagavya very higher microbial population of bacteria, fungi, actinomycetes, N-fixers and P-solubilizers. Further, they have reported that application of these formulations has increased yield in paddy, field bean, maize and soyabean (Devakumar *et al*., 2008) [16]. Higher nutrient status of jeevamrut formulation (2500 L ha^{-1}) resulted in profuse growth in the form of higher dry matter accumulation and yield parameters (Kasbe *et al.*, 2009) [30]. The effect of jeevamrutha on yield of groundnut, increased yield of groundnut (2,050 kg ha^{-1}) was recorded with the treated plot, compared to control (986 kg ha^{-1}) (Upperi *et al.*, 2009). The analysis of the results showed that the yield with application of jeevamrut is 2.775 tons acre^{-1} in Masura and 2.625 tons acre^{-1} in Hamsa variety of rice (Uma Amareshwari and Sujathamma, 2014) [74]. Soil application of jeevamrutha (1000 l ha^{-1}) and foliar spray of panchagavya

(3%) recorded significantly higher number of pods plant^{-1} (15.89 and 15.40), pod weight plant^{-1} (81.58 and 79.42 g) and green pod yield (141.7 and 138.7 q ha^{-1}), as compared to without jeevamrutha (25.0 cm, 6.28, 991.0 cm^2, 13.18, 67.30 g and 117.0 q ha^{-1}, respectively) and without panchagavya application (25.1 cm, 6.32, 1054.0 cm^2, 13.67, 69.56 g and 120.0 q ha^{-1}, respectively) (Basavaraj *et al.*, 2015) [8]. Application of Jeevamrut @ 600 l ha^{-1} (L_1) generated significantly taller plant, cob weight plant^{-1}, green cob and fodder yield and total non-reducing sugar and higher green cob (16145 kg ha^{-1}) and fodder (20068 kg ha^{-1}) yield, harvest index and remained at par with Panchgavya (L_3) and Sanjeevak (L_4) @ 600 l ha^{-1}, respectively (Safiullah *et al.*, 2018) [55]. Application of vermicompost @ 7 t ha^{-1} + Jeevamrut (drenching and foliar spray) significantly influenced yield and nutrient status of soil as well as nutrient uptake and recorded maximum fruit weight (59.33 g), number of fruits per plant (29.13), fruit yield plot^{-1} (24.73 kg) and fruit yield ha^{-1} (366.42 q). Effective Microorganisms (EM) improve the soil health and the growth, yield and quality of crops over a wide range of agroecological conditions (Higa and Parr, 1994) [24]. EM enhances the activities of beneficial indigenous microorganisms, for example mycorrhizae which fix atmospheric nitrogen thereby supplementing the use of chemical fertiliser and pesticides. Improvement in soil fertility has significant positive effect on flowering, fruit development and ripening in crops (Levai *et al*., 2006) [35]. Effect of compost with EM use on wheat yield, this study showed that the compost with EM application increased significantly the production of biomass and grain of wheat in comparison to use of compost without EM and the control (Hu and Qi, 2013) [25]. Inoculation of seed with EM and spraying with it, increased plant yield of tomato by 40% as compared to the control. EM significantly modified commercial yield the seed inoculation with EM cause improvement about 44.6% as compared to the control. Farmyard manure and effective microorganism solution contained both macro- and micronutrients at varying proportions. Application of farmyard manure increased rice yields from 1.35 to 3.31 t ha^{-1}, 1.35 to 3.03 t ha^{-1} activated effective microorganism solution and 1.35 to 3.33 t ha^{-1} in both farmyard manure and activated effective microorganisms when integrated (Paul Saidia and Mrema, 2017) [48]. The highest yield was obtained with the concentration of 1.25% urine applied to leaves and with 1.0% applied to soil. The application of cow urine solution at 1.25% to leaves or 1.0% to soil is recommended for lettuce crops (Oliveira *et al.*, 2009) [43]. Application of FYM 12.5 t ha^{-1} + cattle urine at 34300 L ha^{-1} recorded significantly more number of seeds cob^{-1}, seeds cob^{-1}, test weight number of rows cob^{-1}, grain yield and stover yield (Veeresha *et al.*, 2014) [76]. Application of 100% fertility level and 900 litre cow urine significantly increased the dry matter accumulation in comparison to 50% RDF and control, respectively. Regarding the urine application, the increasing levels of urine application up to 900 L cow urine ha^{-1} enhanced the yield attributes as well as seed and stover yield. Manuring with vermicompost or in combination with foliar spray of vermiwash (5 or 10%) recorded higher number of pods plant^{-1} and significantly increased number of pods plant^{-1}, number of seeds pod^{-1} as compared to that in untreated plot (Mahto and Yadav, 2005) [37]. The effect of vermiwash spray on dry chili yield and concluded that weekly vermiwash the applications increased chili yield by 7.3 per cent (George *et al.*, 2007) [21]. The vermi-product (Vermicompost and vermiwash) treated plants exhibited faster and higher growth rate and productivity than the control plants in black gram (Tharmaraj *et al.*, 2010) [73]. More number of flowers and fruits of brinjal were recorded with the vermiwash at 50 per cent (37.4, 31.6) and followed by 25 per cent (36.6, 27.2) at 90 days (Sundararasu and Jeyasankar, 2014) [70]. Injection 50% recommended dose NPK as drip fertigation in combination with biofertigation of liquid formulation and humic substances was better and comparable way than the other treatments. They reported that fertigation of microbial inoculants and humic substances could be used as a complimentary for mineral fertilizers to improve yield and quality of cow pea under sandy soil conditions which protect the environment chemical pollution and its harmful effect on human and animal health (Abdehamid *et al.*, 2011) [1]. Humic acid treated plants showed improved photosynthetic efficiency, WUE, nutritional status, seed and lint yields and fiber quality compared to untreated plants. In contrast, the soil application of humic acid led to significant reductions in the leaf concentrations of Na, total soluble sugars and free proline. Humic acid has a pronounced positive effect on the growth, yields, fiber quality and WUE of salt-stressed cotton plants (Rady *et al.*, 2016) [49]. The growth and yield parameters of ginger were found to be higher in the plants fed with 50% N (FYM) + 25% N (Neem cake) + 25% N (Vermicompost) + *Azospirillum* (5 kg ha^{-1}) + Panchakavya (3%). The maximum green rhizome yield (23.55 t ha^{-1}) was obtained with the application of 50% N (FYM) +25% N (Neem cake) + 25% N (Vermicompost) + *Azospirillum* (5 kg ha^{-1}) + Panchakavya (3%) per hectare (Chitra and Vinothini, 2020) [13].

d) Effect of organic formulations on biochemical-quality parameters of turmeric

Interaction effect of jeevamrutha and panchagavya was significant in enhancing the grain yield of cowpea besides improvement in quality parameter like protein (Sutar *et al.*, 2017). The protein content (%) and protein yield (kg ha^{-1}) of pigeonpea increased significantly with application of FYM @ 2.5 t ha^{-1} + vermicompost @ 1 t ha^{-1} + two times jeevamrut @ 500 lit. ha^{-1} (30 and 45 DAS) as compared with control (Janbhare, 2010) [27]. Higher oil and protein content and yield under the treatment, application of FYM @ 7.5 t ha^{-1} + Jeevamrut (N equivalent) + *Rhizobium* + PSB as compared to application of FYM only (Ravikumar *et al.*, 2011) [53]. Tomato's grown in EM has significant higher values of beta carotene, brix values and vitamin C contents. Hence, EM compost can be applied to supersede the use chemical fertilizer in crop production and thus minimizing both ecological and environmental effects caused using agrochemical (Shekha *et al*., 2017) [63]. Maximum shoot and root length of okra were recorded in T_1 (2.9 cm) and T_3 (2.l cm) respectively. The 100% seed germinated in all vermiwash treated group and maximum chlorophyll content was recorded in T_2 (4.91 mg g^{-2} dry wt.) as compared to control (Senthilmurugan *et al.*, 2018) [62].

Conclusion

Organic nutrient management and organic formulations play a decisive role in enhancing the yield, quality, and sustainability of turmeric cultivation. Turmeric, being a long-duration and nutrient-exhaustive crop, responds positively to the application of organic manures such as farmyard manure, vermicompost, poultry manure, neem cake, and compost, either alone or in combination with organic formulations. These inputs consistently improved yield attributes, fresh and cured rhizome yield, and curing percentage across diverse agro-climatic conditions. Organic nutrient sources also significantly enhanced biochemical quality parameters of turmeric, particularly curcumin content, essential oils, oleoresins, and dry recovery, thereby improving market value and consumer acceptance. Traditional organic formulations such as jeevamrut, beejamrut, panchagavya, vermiwash, cow urine, humic acid, and effective microorganisms. These formulations enhanced soil microbial activity, nutrient availability, and physiological efficiency of plants, resulting in better growth, yield, and quality. Integrated use of organic manures and liquid organic formulations proved superior to sole application, indicating strong synergistic effects.

Overall, the findings emphasize that organic nutrient management is a viable and eco-friendly alternative to chemical fertilizers for turmeric cultivation. Adoption of suitable organic manures and organic formulations not only sustains soil health and productivity but also meets the growing global demand for high-quality organic turmeric, ensuring long-term economic and environmental sustainability.

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