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Effect of integrated nutrient management on growth and yield of tomato: A review

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Abstract
In India mostly the agriculture depends upon the organic inputs. Integrated nutrient management is the method to improve the farmer productivity with the efficient use of organic inputs like vermicompost, green manures, poultry manure, Panchagavya and biofertilizers. These all-organic fertilizers improve the quality parameter, growth parameter and improve the soil properties of soil and make the soil healthier for long term basis. From past decays, most of the farmer using chemical fertilizers that decrease the fertility of soil. But now a days most of the farmer using integrated nutrient management in combination with organic and inorganic and biofertilizers that provide good quality of food and make the soil healthy. Integrated nutrient management is also help to improve the crop productivity and checking the emerging of micronutrient deficiencies. The present study deals with the effect of integrated nutrient management on crop yield, growth and quality of tomato plant.

Keywords: INM, organic fertilizers, biofertilizers, bio manures, tomato

Introduction
Vegetables act as a protective food. Vegetables is rich in essential nutrients like carbohydrates, proteins, vitamins such as vitamin and minerals like potassium, phosphorous, calcium, sodium, manganese etc. which is important for human growth and also maintain the health. Vegetables not only contains nutrients but also have fibers which helps to cure constipation. According to ICMR, approximately 300g vegetables are needed per capita per day in which 100g root crops, 125g leafy vegetables and 75g other vegetables are added in every person diet, but vegetables is not enough produced in our country because of 20-40% post-harvest losses, pre harvest losses of vegetables and large population. India is the second largest producer in vegetables after china and producing 98579 million metric tons on an area 6648 million hectare (NHB 2019). The total vegetables production during this time increased by approximately 2-3 times and the productivity increased 1 to 2 times. India shares near about 37% of the total exports of agricultural products but share of vegetables and vegetable products are more as compared to other horticultural commodities. The maximum production of vegetables produced by Odisha (8466.17 MT) followed by Andhra Pradesh.

Basically, Indian subcontinent are capable for producing higher horticultural and field crops due to vast diversity of land, soil, climatic conditions etc. After green revolution, different improved cultural practices or scientific technologies should be adopted, which will lead to increase the vegetable production. Hence, the vegetable area, production or productivity increase year after year (Kumar *et al*. 2017) [29]. Apart from that, production of vegetables is comparatively low as compared to other developed countries because in India farmers are more focus on cash crops or pulse crops which gives more profit as compared to vegetables. After independence, the population is increase day by day and due to rapid growing population, the field area goes declined and due to this the production of horticultural or field crop is not enough produced in our country, so every person is not getting proper vegetables in diet, which cause the problem of malnutrition. Now, in India basically, the Cole crops, tomato, brinjal, okra, bulb crops, root crops etc. are grown at commercial levels which fulfill the needs of humans and provide sufficient nutrients which reduce the risk of disease.

Tomato (*Lycopersicum esculentum* Mill.) is one of the most important crops in the world belonging to the family Solanaceae. Tomato has the chromosome number is 2n=24. It is a warm season crop but generally grown throughout the year. Tomato contains lycopene content. Tomato is mostly grown in home garden for fresh consumption. Tomato is grown under open and protected condition throughout the world. Generally, the cultivation of tomato under open conditions is very less due to frost injury during winter and low temperature in summer.

Polly house is a best solution to for successful cultivation of tomato in winter and summer season. Tomato is basically grown all over the world for its higher nutritive values. Tomato is grown all over the world. It is also known as poor man apple.

Tomato is a long duration crop but it is grown as annual. Tomato is susceptible to frost and it can be grown wet and dry season. In tomato high rainfall during growth is harmful. It requires 24-40 c temperature for better growth and night temperature 22. It is survived in all kind of soil but it is best suitable for medium black and light clayey soils that is rich in organic matter. It requires pH ranges from 6.0-6.8. Ripe tomato contains 94% water and organic acid. Tomato is also called as protective food and it is a good source of income for small and marginal farmers.

Tomato has second rank after potato in India and in the production of world. In India tomato growing states are Punjab, Haryana, Maharashtra, Uttar Pradesh, Karnataka and Bihar. Tomato is a self-pollinated crop and it is originated from Peru of South America. Generally, tomato was introduced by the Portuguese. Tomato is grown in tropics and subtropics of the world. It has been cultivated in commercial fields under green house and poly house conditions and soil less culture or hydroponic systems. Tomato contains source of vitamins (A, B, C and Fe), minerals and antioxidants which are essential for human health. Tomato is a good source of vitamin A, B, C, Fe and also it has a good nutritive value. Generally, tomato is consumed fresh as well as in processed form. Tomato is eaten raw or cooked and it is used for making puree, soup, ketchup, paste and powder. It also reduces the risk of stomach cancer. It contains lycopene content which reduce the risk of prostate cancer.

Now a days, in different countries various challenges is facing in respect to provide chemical free food for the growing population. Due to use of synthetic fertilizers vegetable yield is decline day by day unwanted use of synthetic fertilizers reduce soil fertility, kill the beneficial micro-organisms, and more over these chemicals interfere in our ecosystem (Diacono and Montemurro, 2010). Different pesticides are spray over the plants and when people consumed food these chemicals are directly enter into the food chain which causes numerous diseases like, cancer, asthmatic problems, skin allergies etc. Therefore, to avoid these problems, peoples preferred more organic food. Moreover, due to organic farming different organic amendments are used in production of vegetables such as, biofertilizers, vermicompost, FYM, compost, BD manure and some fermented liquid bio enhancer should be used such as, panchagavya, amritpani, jivamrit etc. which is free from chemicals and eco- friendly, which not only improve the soil but also improves the plant health as well as human health and moreover sustain the ecosystem (Radhika & Savita 2020). Organic fertilizers also improve the physical and chemical properties of soil and balance the nutrient supply. Organic fertilizers improve the physical, chemical and biological properties of soil (Kumar *et al*. 2011). In this respect, organic farming which is an eco-friendly and natural way which sustains the agriculture and promote the higher yield as well as provide chemical free food for human consumption. Different researchers investigate that, vegetable production goes increase with the combined application of different organic amendments with proper concentration and at proper stage or time. Apart from that different studies also concluded that, if chemical fertilizers are used with the combination of organic manure, it also improves the plant growth or yield with minimum degradation of soil or pollution.

Organic manures

Organic manure is one of the most important and commonly used organic nutrient component in Integrated nutrient management. These are derived from organic products like vegetables compost, animal waste and agricultural excreta. Organic manure consists Vermicompost manure, FYM, Sheep manure, fish manure, neem cake, oil cake and poultry manure. Generally, the nutrient value of organic manure is not comparable to inorganic fertilizers. Organic manures like vermicompost, FYM and poultry manure are rich source of nutrient. Organic manure plays a significant role in maintaining soil fertility (Tandon, 1992). Vermicompost, FYM and poultry manure release nutrients decomposition. The bulk organic manures contain small amount of nutrients and they are applied in large quantities. FYM contain 0.5-1.0 N, 0.15-0.20 P2O5 and 0.4-0.6 K2O

Advantages of organic manures

1. Organic manure improves the physical properties of soil.
2. It also supplies the micro and macro nutrient to the plant.
3. Organic manure also provide nutrient to the soil.
4. Organic manure increases the fertility of soil.
5. Organic manure improves the water holding capacity and improves soil tilth.
6. It also increases the nutrient availability in soil.
7. Organic manure has high cation exchange capacity and it increases the phosphorus availability.
8. It also increases the yield and long-term usage of organic manure gave maximum output.

Farm yard manures

FYM is used as organic manure in vegetable crops. FYM provide all essential nutrients to the plant because in FYM numerous beneficial micro-organisms are present which secretes some substances and this substance act as a growth regulator which improves the soil structure or soil fertility as well as also improves the plant growth. It is also improving the water holding capacity, microbial activity and cation exchange capacity. It the decomposed mixture of cow dung and cow urine of farm animals. Generally, farm yard manure consists 0.5%N, 0.2% P2O5 and 0.5% K2O.

Table 1: Effect of FYM on tomato

With the application of 50% N through FYM + 50% N through urea recorded that maximum plant height (55.6 cm), more number of branches, no. of fruits per plant, fruit weight and highest yield.	Reddy *et al*. (2002)
With the application of RDF + FYM have maximum plant height, more no. of branches, leaf area, chlorophyll content, fruit yield and net returns	Arahunashi (2011)
Application of 50% FYM +50% RDF have highest plant height, more no of flower, fruit yield and more no of fruit per cluster.	Rajya Laxmi *et al*. (2015)
Application of FYM @ 8t/ha gives highest yield production (9.57t/ha)	Hussein Alhrout *et al*. (2018)

Vermicompost

In India, the yield of vegetable crops is declined due to decrease the soil fertility and more use of chemical fertilizers or synthetic fertilizers in large amount. So, it is necessary to improve the soil fertility to obtain more yield and quality

parameters. Vermicompost is the controlled process of earthworm that converts the organic wastes materials (like farm waste, kitchen waste and other bio-waste) into plant available nutrient rich in organic fertilizers (Kale 1998; Nagavallemma *et al*. 2006). Vermicompost has not only positive affect on soil quality, plant growth and yield but it also enhances the nutritional value. Vermicompost improves the electric conductivity, bulk density, water holding capacity, pH value, organic matter content, micronutrient, macro nutrients and biological properties of soil (Sharma and Garg, 2017; Swami and Bazaya, 2010) [7]. It also improves the structure and texture of soil and reduces the soil erosion. Generally, epigeic earthworm Eisenia fetida is used for making the vermicompost and decompose the organic wastes to the soil. Culturing of earth worm is known as vermiculture. It also includes higher microbial population activities and contains NPK. Vermicompost act as a plant growth regulator which increase the growth, yield and quality parameter of crops. Vermicompost consist both macro and micronutrient that is nitrogen (1.6%), Potassium (0.7-0.8%), Zinc, manganese and phosphorus (0.7%). These nutrients are used for large scale production in vegetables because it has a capacity to reform the soil fertility and increase the productivity (Usha Kumari *et al*. 2006).

Preparation of vermicompost

Generally, vermicompost is prepared by two methods that is pit method and bed method. In pit method organic waste is collected and transfer into pits. On the other hand, bed method is very easy in which beds of organic waste are prepared. For making the vermicompost firstly mix the waste material and then make the cow dung slurry and sprinkler the water regularly on it. After doing this add 2-3 inch of soil at the bottom of the pit and then placed the organic waste materials (FYM, Kitchen manure etc.) on it. Fill the tank up to 0.5-1.0 feet and then release the earthworm (red earthworm *Eisenia fetida*) and then covered it properly. Vermicompost is ready after 24 day to use.

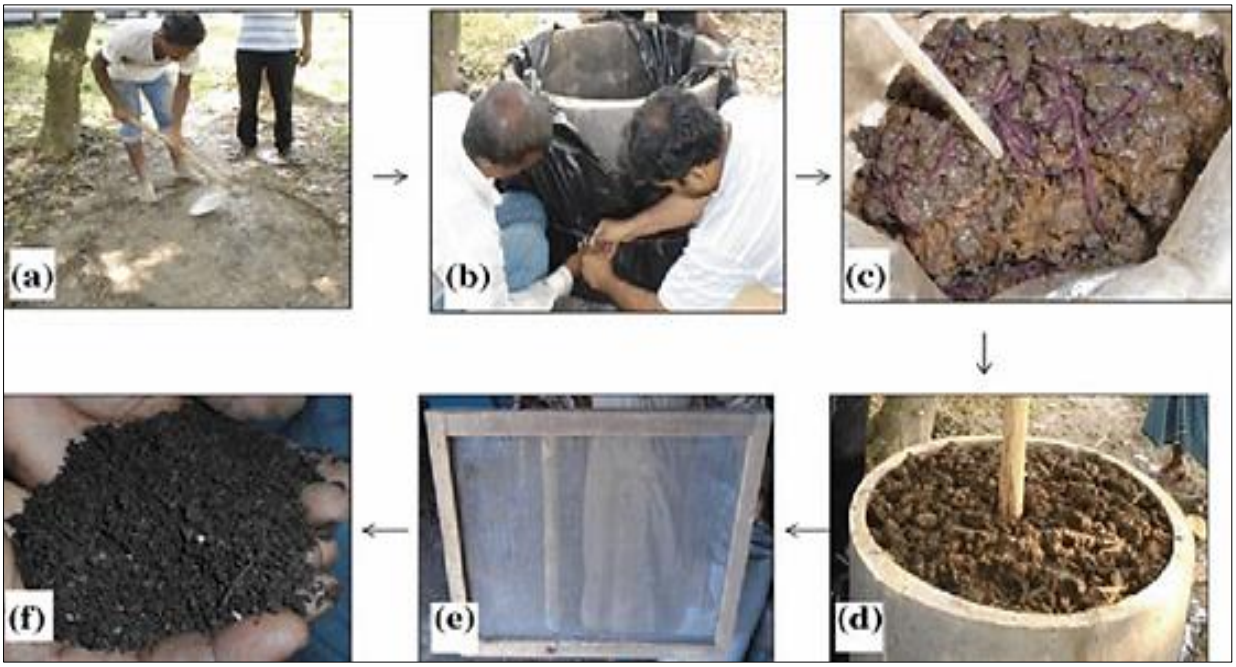

Table 2: Effect of vermicompost on tomato growth and yield

It has been found that Germination percentage is maximum with the application of 15% vermicompost	Rakesh Joshi and Adarsh Pal Vig (2010)
Vermicompost with NPK show 73% better fruit yield	Goutam Kumar Chanda *et al*. (2011)
Vermicompost 20t/ha increase no. of fruits, dry weight of shoot and root and fruit weight	Md. Abul Kahem *et al*. (2015) [37]
Application of vermicompost @ 20q/ha and boron @ 10kg/ha increase the vitamin C content, lycopene and sugar content in tomato.	Indira Sarangthem *et al*. (2015)
25% vermicompost with peat, gravel and perlite increase the growth parameter like plant height	Margit Olle (2016)
Application of 45 and 90 kg vermicompost increase the growth and yield of tomato	Jessie Sabijon *et al*. (2018) [17]
Vermicompost increase plant height, stem girth and leaf numbers.	Balasubramani Ravindran *et al*. (2019) [6]
Application of vermicompost @ 2t/ha recorded highest growth and yield of tomato.	Mukesh Kumar Meena and K.S. Verma (2019)
Vermicompost promotes plant growth and suppress plant pathogens	Juana Munoz-Ucros *et al*. (2020) [18]
100 gm dose of vermicompost increased tomato yield.	DI Stepanova *et al*. (2021) [10]

Poultry manure

Poultry manure is prepared by using chicken feces and it act as organic source. It is the most beneficial organic manure produced by the livestock (Omisore *et al*. 2009). In these solid and liquid excreta are collected together and no urine loss. In poultry manure urea and ammonium are present in small amounts apart from that uric acid present in more quantity (Krogdahl and Dahlsgard, 1981). It is rich in N, P, K but litter consist Ca, Mg, S and some micronutrients (Mullins *et al*, 2002). They also provide high amount of Phosphorus to the plant than other organic source (Garg and Bahla, 2008). It also improves the soil tilth and soil chemical properties and enhances the soil biological activities (Michael and Geoige, 1998 and Maiison and Miles, 2005).

Table 3: Impact of poultry manure on growth and yield of tomato

Poultry manure @ 8 t/ha significant effect on number of leaves and shoots length of tomato.	Eliakira Kisetu and Peter Heri (2014) [12]
Poultry manure @ 10t/ha increase tomato growth and yield.	C.V. Ilodibia and M.U. Chukwuma (2015) [9]
Combine use of poultry manure and urea @ 50kg urea + 8t/ha PM and 100U + 4t/ha PM good for cultivation of tomato and increase growth parameters and yield of tomato	Ewulo, B.S. *et al.* (2016) [16]
Poultry manure @10 t/ha significant increase the maximum nodes, no. of leaves, flowers and fruits of tomato.	Adeyeye A.S. *et al.* (2018) [4]
Poultry manure have maximum no of fruits, vine length, no of leaves and fruit yield of tomato	Abdulmaliq SY *et al.* (2019) [2]
Application of 75% RD+ Poultry manure has significant effect on plan height, no of flower cluster, no of fruits and fruit yield in tomato.	Mohammad Idris Ali Howlader *et al*. 2019 [20]
Poultry manure significantly ($p< 0.05$) maximum plant height, stem girth, fruit weight, number of fruit and number of leaves	Abejide Dorcas Ropo *et al*. (2020) [3]
Poultry manure @20t/ha significantly produced highest fruit yield in tomato.	Ehizogie Joyce Falodun (2020) [11]
Poultry manure @ 5 t/ha has highest plant height, flowering and fruits in tomato	F.B. Musa *et al*. (2020) [20]

Biofertilizers

Biofertilizers are more economical and eco-friendlier that can play a vital role to reduce the use of more chemical fertilizers. It contains millions of the living microorganism that provide the nutrients to the plant. Biofertilizers consist artificial multiplied culture of microorganism that is Cyanobacteria, Acetobacter, Pseudomonas and Rhizobium. These all biofertilizers enhance the soil fertility and soil improvement, stimulate the plant growth and provide higher crop yield and it is also controlling the soil borne diseases. Biofertilizers are released by roots and bacteria. These are play an important role in the uptake of mineral nutrient (Boraste *et al*. 2009). Biofertilizers are the cheapest source of macro and micronutrient. These are non- bulk in nature. Biofertilizers fix the 50-200kg/ha nitrogen. Biofertilizers like Azospirillum fix the atmospheric nitrogen in soil and also produce growth promoting and antifungal substances. Azospirillum are beneficial for non- leguminous plants. It also acts as plant growth hormone. Azotobacter biofertilizers is a non-symbiotic, gram negative, free living nitrogen – fixing bacteria and heterotrophic. Azotobacter fix the nitrogen about 20-25kg/ha. Its genus consists 6 species but A. chroococcum is mostly used in all over the world. Azotobacter is also act as a plant growth regulator that is thiamine, gibberellins and riboflavin. Phosphate solubilizing bacteria are mostly applied in inorganic fertilizers, due to its low levels of solubility and mobility these are unavailable to vegetable crops and it is also improving the phosphate uptake of plants in different ways.

Table 4: Effect of biofertilizers on growth and yield of tomato

Azotobacter with 150kg N + 60kg P + 60kg K/ha has maximum plant height, number of fruits/plants, weight of fruits/plant and fruit size	Gajbhiye R.P. *et al*. (2003) [16]
100% P with seedling dip in PSB 1:10 solution gave higher leaf area index, plant height, more no. of fruits, fruit weight and fruit yield	MK Poonia and BL Dhaka 2012 [19]
PSB with RDF have superior effect on plant weight (639.33g) and dry weight (129g)	Mohit Kumar *et al*. (2018) [27]
Azatobacter along with RDF gave maximum plant height, number of branches, leaf area.	Barinderpal Singh *et al*. (2018) [8]
Azospirillum and PSB along with RDF have highest plant height, number of leaves per plant and minimum days to 50% flowering.	Vamadeva Angadi *et al*. (2017) [29]
Azatobacter with Azospirillum significantly ($P< 0.05$) gave maximum yield.	Ramakrishan and G. Selvakumar (2012) [24]
Azotobacter along with inorganic fertilizers improve the vegetative growth and Azospirillum improves the yield attributes in rainy season tomato	Barinderpal Singh *et al*. (2017) [7]
Application of RDF + Azotobacter + PSB + VAM gave maximum plant height, fruit length, fruit diameter, fruit weight and fruit yield.	Arka Rakshak *et al*. (2017)
Azotobacter and mycorrhiza along with compost 15t/ha had a positive effect on tomato growth like plant height, shoot fresh and dry weight	Wael A. Marajan *et al*. (2017) [30]
Application of biofertilizers (PSB @ 2.5 Kg/ha and Azospirillum @ 2.5 Kg/ha) + 100% RDF gave maximum growth, fruit yield and quality of tomato.	Rohit Kumar Singh *et al*. (2017)
Application of biofertilizers along with RDF recorded maximum shoot and root length and germination	Vamadeva Angadi *et al*. (2017) [29]

Panchagavya: Panchagavya is a fermented liquid-based product which is prepared with five cow products such as cow dung, cow urine, cow milk, cow ghee and cow curd. Panchagavya is prepared since in ancient times and mostly used in agriculture as source of nutrients and it was first investigated by Natarajan (president of rural community action center) and also, he wrote a one book on Panchagavya i.e., ''Book on Panchagavya'', and he mention in his book that, in Ayurveda Panchagavya is very important for plant health as well as also healthy for human beings and animals (Natrajan, 2002). Basically, it is a simple liquid bio-enhancer based products which act as a plant growth hormone and sustain the immunity in plants. Different micro and macro nutrients such as nitrogen, phosphorous, potassium or zinc, manganese, calcium, sodium etc. along with amino acid, vitamins, growth hormone (auxin and GA) present in it, which significantly increase the growth and yield of the crop. Moreover, it also contains the useful microorganisms such as azotobacter, PSB etc. which improves the physical, chemical and biological properties of the soil and also it improves the nutrient quality of soil (Xu and Xu 2000) [31]. More over Panchagavya act as a phytohormones which significantly enhanced the root growth and all such roots helps in maximum translocate the nutrients and water from roots to all aerial parts whereas, it also regulates the chlorophyll content which increased the rate of photosynthetic pigments which influence the plant growth and yield. The main important features of Panchagavya are that, it has ability to restore the crop productivity when land is converted from conventional to fully organic (Borgohain *et al*. 2020).

Fig 1: Ingredients used for making panchagavya

Flow chart for preparation of Panchagavya

Mix cow dung (5 kg) along with cow ghee (1 kg)

↓

Kept the solution undisturbed for 3 days (mix clockwise and anticlockwise direction)

↓

Add cow urine (3L) along with water (10 l)

↓

Kept the solution undisturbed for 15 days and stir it once in the morning or once in the evening

↓

Now mix other ingredients such as, sugarcane juice (3L) or jaggery (500 g) Coconut water (3L), ripened banana

↓

Again, stir the solution in clockwise direction or anticlockwise direction and kept the mixture under shade and after 30 days it is ready to use

Table 5: Physical, chemical and biochemical and microbiological properties of Panchagavya

Physical properties	Chemical properties	Biochemical properties	Microbiological properties
pH 6.82	Total N (ppm) 229	IAA (ppm) 8.5	Fungi 38800
EC (dSm-2) 10.22	Total P (ppm) 209	Ga (ppm) 3.5	Bacteria 2610000
	Total K (ppm) 232	Acetate 60-68%	Lactobacillus
	Na (ppm) 90	Propionate 14-16%	Methanogen 250

Table 6: Effect of Panchagavya on tomato

Panchagavya @ 3% enhance the growth characters of tomato	Parmar *et al*. (2020) [23]
Panchagavya @ 3% gave maximum fruit yield and maximum net return	S. Marimuthu *et al*. (2019) [25]
Panchagavya 4% gave maximum growth and yield of tomato.	Sanjiv Yadav *et al*. (2019) [26]
Panchagavya with high disease resistance, gave more no of plants and maximum plant height	A. Sathya *et al*. (2017)
Panchagavya @ 3% and moringa leaf extract spray @25ml/plant gave higher plant height and no. of branches per plant.	Muthuvel (2002)
Panchagavya @ 3% increase the yield attributes.	Birendra and Christopher (2007)
Panchagavya, jeevamruth, beejamruth gave maximum yield as compared to RDF alone.	Nikeemas Gore and MN Sreenivasa (2011) [22]
Panchagavya @ 4% along with Vermiwash increase the population of microorganism which release the growth promoting hormones.	Kumar S *et al*. (2019) [2, 26]

Table 7: Effect of inorganic fertilizers (NPK) on growth and yield of tomato

Application of 50% RDF + FYM @10t/ha + Poultry manure @5t/ha + biofertilizer recorded highest number of leaves per plant, fruit weight, ascorbic acid content, yield and fruit length.	Singh, P.K. Jain *et al*. (2015) [1]
Application of 75% RDF + 25% FYM + Azospirillum gave maximum fruit yield in tomato.	ML Meena *et al*. (2017)
Application of vermicompost + Azotobacter + PSB increases the growth parameter that is plant height, no of branches, fruit weight and highest yield	Kumar Amrit *et al*. (2017)

Application of Vermicompost @ 6t/ha along with biofertilizers (PSB 2Kg/ha and Azospirillum 5kg/ha) increase the fruit yield and quality of fruit.	A.K. Singh *et al*. (2018)
Application of vermicompost @10t/ha + FYM @ 20t/ha gave highest net return and B:C ratio and gross return	Bairagya M.D. *et al*. (2019)
Application of organic fertilizers (50% FYM + 50% vermicompost) gave highest lycopene content with 50% inorganic fertilizers	M. Muthu Kumar *et al*. (2019) [25]
Application of 50% RDF + 10t/ha FYM + 5t/ha poultry manure + Biofertilizers show highest fruit length, fruits per plant, more no of leaves per plant and highest yield.	A. Singh *et al*. (2015) [1]
Application of Neem cake (50% + Vermicompost (50%) + PSB + Azospirillum show highest fruit weight, fruit length and fruit diameter.	Usha Parmar *et al*. (2019) [28]

Table 8: Combine effect of organic manure and biofertilizer on tomato crop

Application of 50% RDF + FYM @10t/ha + Poultry manure @ 5t/ha + biofertilizer recorded highest number of leaves per plant, fruit weight, ascorbic acid content, yield and fruit length.	Singh, P.K. Jain *et al*. (2015) [1]
Application of 75% RDF + 25% FYM + Azospirillum gave maximum fruit yield in tomato.	ML Meena *et al*. (2017)
Application of vermicompost + Azotobacter + PSB increases the growth parameter that is plant height, no of branches, fruit weight and highest yield	Kumar Amrit *et al*. (2017)
Application of Vermicompost @ 6t/ha along with biofertilizers (PSB 2Kg/ha and Azospirillum 5kg/ha) increase the fruit yield and quality of fruit.	A.K. Singh *et al*. (2018)
Application of vermicompost @10t/ha + FYM @20t/ha gave highest net return and B:C ratio and gross return	Bairagya M.D. *et al*. (2019)
Application of organic fertilizers (50% FYM + 50% vermicompost) gave highest lycopene content with 50% inorganic fertilizers	M. Muthu Kumar *et al*. (2019) [25]
Application of 50% RDF + 10t/ha FYM + 5t/ha poultry manure + Biofertilizers show highest fruit length, fruits per plant, more no of leaves per plant and highest yield.	A. Singh *et al*. (2015) [1]
Application of Neem cake (50% + Vermicompost (50%) + PSB + Azospirillum show highest fruit weight, fruit length and fruit diameter.	Usha Parmar *et al*. (2019) [28]

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