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Effect of Integrated Nutrient Management for Growth, Yield and Post-harvest Quality of Tomato

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The cultivated tomato *Solanum lycopersicon* L., a commercial annual crop that is grown all over the world for local consumption or export purpose. It belongs to the Solanaceae family and has diploid chromosome number (2n= 2X= 24). Application of fertilizers, insecticides and herbicides is crucial for improving productivity per unit area, however excess usage more than that of a recommended dose can lead to issues including environmental contamination (air, water and soil pollution). According to a thorough study, farmers exposed to chemical insecticide spray for a period of 18 months experience impaired vision symptoms like eye stinging or burning (18.42%), dry sore throat (21.05%), blurred vision (23.68%), nose burning (28.9%), shortness of breath and excessive sweating (34.2%), and skin itching or redness (50.0%). The purpose of this brief review article is to

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explore the function of various organic and inorganic nutrient sources in tomato crop by analysing previous works and studies. Integrated Nutrient Management (INM) is an approach that boosts the agricultural production and safeguards the environment for future generations.

Keywords: Tomato; INM; organic and inorganic nutrient sources; growth; yield and quality.

1. INTRODUCTION

The cultivated tomato *Solanum lycopersicon* L., a commercial annual crop that is grown all over the world for local consumption or export purpose. It belongs to the Solanaceae family and has diploid chromosome number (2n= 2X= 24). The role of various organic and inorganic source of nutrients in tomato is examined in this brief review article by analysing earlier research and investigations. A fertilizer is any substance which is of natural or synthetic origin, that is applied to soils in order to provide one or more essential plant nutrients and hence addressing plant nutritional deficiencies to improve better plant growth coupled with higher returns in the form of output yield. Synthetic fertilizers have a negative effect that begins with the manufacturing process since they produce hazardous byproducts and toxic gases such as CO_2, CH_4, and NH_4 *etc.,* that significantly reduce the air quality and cause alarming environment conditions. Also, application of fertilizers, pesticides and herbicides plays crucial role in reaching very high productivity per unit area, but their excess use can lead to issues like environment pollution (air, water and soil pollution).In light of all the aforementioned issues, farmers must manage soil fertility and nutrients in an integrated manner in order to satisfy the demand of expanding population for food in the first decade of the twenty-first century. Integrated Nutrient Management (INM) is an approach that increases the agricultural output and safeguards the environment for future generations [1]. As a result, nutrient management is a strategy that combines both organic (farm yard manure, compost, green manure, gobar gas plant manure, bone meal, steamed bone meal, oil cake, fish manure, wood ash, sewage, sludge, coir pith, sugar cane press mud, biological sources, bio-fertilizers) and inorganic (major and micro nutrients) plant nutrients to achieve maximum crop productivity, prevent on-site soil degradation [2] and supports to meet future food supply needs.

1.1 Importance of Nutrient Application in Vegetable Crops

Proper crop growth and development requires sixteen key plant nutrients. Each nutrient has an equal importance and necessary for the plant in proper amounts and these nutrient components are divided into different categories based on their essentialities in plants. There are three types of nutrients like essential (macro) nutrients, secondary vitamins and micronutrients [3]. Nutrients enhances the growth and root development of the soil flora and fauna [4]. Nitrogen (N) plays a vital function in the plant metabolism and hence it is recognised as a key nutrient for growth and development [5]. The primary factor for the yield reduction in global agricultural production system is low phosphorus (P) availability and less availability of phosphorus at all phases of crop growth can minimize yields up to 5-15% [6,7]. Magnesium (Mg) is a significant component of cell walls, is pivotal for the process of photosynthesis in the plants. Sulphur (S) is now considered as fourth main nutrient after N, P and K and its significance is being acknowledged due to its significant contribution to crop quality improvement. Boron (B) is a micronutrient crucial for plant growth and is required for the synthesis of cell wall, transport of sugars, cell division, cell development, auxin metabolism, good pollination and fruit set, seed development, synthesis of amino acids and proteins, the formation of nodules in legumes and regulation of carbohydrate metabolism [8]. Zinc (Zn) is regarded as indispensable component for the plant growth and has been found in a variety of enzymes involved in various biochemical activities.

1.2 Importance of Organic Manure in Enhancement of Quantitative Traits

“The organic manures have a pivotal role in stimulating plant growth, yield and yield attributes of various vegetables crops” [9,10]. “Organic fertilizers provide crops with a balanced amount of essential nutrients and macronutrients for crop growth and development, which furnishes plants with more resilience to cold. The differential response of plants to different doses of organic manures is due to the production of a lesser volume of growth-promoting components” [11]. “Some of the most often reported outcomes with the application of vermicompost treatment include root initiation, enhanced root biomass, superior plant growth and development, and

occasionally alterations in plant morphology" [12]. "Earliness with the application of organic manures may be attributed to the quicker enhancement of vegetative growth and availability of strong, adequate reserve food supply for differentiation of vegetative buds into flowers" [13]. "Vermicompost contains most nutrients in plant friendly forms, including phosphates, exchangeable calcium, soluble potassium and other macronutrients with a significant amount of beneficial microbes, vitamins, and hormones that have positive influence on plant growth and yield" [14]. A natural organic liquid fertilizer called seaweed extract which contains vitamins, auxins, gibberellins, regulators, plant growth hormones, carbohydrates, and other nutrients that promotes faster seed germination and preserves soil fertility [15].

Application of NPK at recommended dose ensured quicker availability of major nutrients during early stages of crop growth as compared to sole application of organic manure, supported rapid new cell formation and elongation, produced the best possible carbohydrate metabolism in crop and increased dry matter accumulation. Hence, miximg manure with synthetic fertilizers might accelerated the process of mineralization of the labile fractions of organic matter and thereby increased its optimum decomposition. Organic manures such as farmyard manure (rich in potassium), vermicompost (higher concentrations of nitrate-nitrogen and lower concentrations of ammonium-nitrogen) and poultry manure (least C:N ratio) boosted the water-holding capacity of soil and maintained at ideal moisture for longer period of time. It might had gradually increased the amount of available carbon in the soil, acting as an energy source to facilitate the development of extremely diverse microbial communities with a variety of functional characteristics, ultimately supported dissolution and availability of nutrients (N, P, K and micronutrients) for crop plants [16]. Additionally, by increasing the root density, active adsorption area, and root surface phosphatase activity, the incorporation of organic sources into soil could enhance crop plants' root morphological characteristics, root TTC (Tri phenyl Tetrazolium Chloride) reducing capacity, Nitrate Reductase (NR), and Glutamine Synthetase (GS), and reflect the effectiveness of N uptake and utilisation by crops. (Zhang *et al.,* 2020). Humate, a non-nutritional growth-promoting substance, is present in organic manures and contains growth regulators like hormones in trace amounts (compounds with gibberellin, cytokinin, and auxin-like actions have been found). It is believed that humus and humus-like compounds promote plant nutrient absorption and metabolism, affecting protein synthesis, and exhibit hormone-like activity. (Bachman and Metzger, 2008). There was an increase in cell lengthening, photosynthesis, carbohydrate metabolism, photosynthates translocation to different plant parts, synthesis of protein, amino acids, and nucleic acids, and activation of plant enzymes as a result of the availability of various macro and micronutrients in the soil during the crop growth period and there by resulted in the enhanced plant growth (biomass production) and yield [17,18]. However, continuous addition of organic nutrient sources and inorganic fertilizers (NPK) might encouraged the development, activity and metabolism of soil microbes. This, in turn, increased the activity of the enzymes dehydrogenase β-glucosidase and e-fluorescein diacetate (FDA) activity in the soil which in turn promoted the degradation of biomass [19].

1.3 Importance of Organic Manure in Enhancement of Qualitative Traits

Organic manures naturally improves the soil physical, chemical and biological characteristics of the soil while conserving its capacity to retain moisture. This results in more desirable crop productivity along with maintaining the quality of crop production. Organic fertilizers increase the nutrient availability, provide beneficial effects to the soil and helps to maintain plant quality [20,4]. To improve and help to, follow Use an organic potassium product such as kelp meal or greensand, to enhance fruit quality and aid in the prevention of plant diseases.

1.4 Effect of Integrated Nutrient Management on Growth Parameters

Meena and Verma [21] conducted an experiment on growth and yield of tomato (*Solanum lycopersicum* L.) with different sources of organic manures and bio fertilizers. On the basis of experimental findings, application of Recommended Dose Fertilizer (100:50:60 NPK kg/ha) resulted into maximum plant height of 117.13 cm and number of primary branches (12.07). Chauhan et al. [22] carried out an experiment on effect of varieties and integrated nutrient management on growth and yield of chilli (*Capsicum annuum*). Significant increase in plant height (71.6 cm) and number of branches per

plant (24.7) at 90 days after transplanting were recorded with application of Recommended dose of fertilizer and vermicompost 2.5 tons/ha. Mengistu et al. [23] studied the integrated use of excreta-based vermicompost and inorganic Nitrogen, Phosphorus fertilizer on tomato (*Solanum lycopersicum* L.) fruit yield, quality and soil fertility at Dire Dawa. Results recorded that maximum plant height (75.20cm) and number of primary branches (8.90) were obtained with the application of 75 percent RDF and 11.25 ton/ha vermicompost. Rani et al. [24] evaluated the integrated nutrient management practices on growth, yield and economics of green chilli cv. Pusa Jwala (*Capsicum annuum* L.). Findings revealed that the combined application of 150 kg nitrogen/ha + 10 t/ha of FYM + 0.5 t/ha of neem cake resulted into maximum plant height (59, 58 cm) and number of branches per plant (23, 23) respectively. Singh et al. [25] carried out an experiment at research farm of ICAR research complex for NEH Region, Mizoram to study the effect of vermicompost and NPK fertilizer on morpho-physiological traits of plants, yield and quality of tomato fruits (*Solanum lycopersicum* L.). According to the research findings, maximum plant height (96.4cm and 106.5cm) and stem thickness (14.7mm and 16.2mm) was recorded in T_4 (NPK 30:15:15 kg/ha and vermicompost 11.25 t/ha) and T_3 (NPK 60:30:30 kg/ha and vermicompost 7.50 t/ha) respectively in both the years of study. Narayan et al. [26] studied the effect of organic manures and inorganic fertilizers on fruit yield of tomato and reported that the combined application of FYM (20 t/ha) and recommended dose of NPK (150:60:60 kg NPK / ha) recorded maximum plant height (47.06 cm).

1.5 Effect of Integrated Nutrient Management on Yield Parameters

Mohit et al. (2019) conducted an experiment on the impact of integrating organic and inorganic sources of nutrients on tomato growth, yield quality, and profitability (*Lycopersicon esculentum* Mill.) var. Pusa Rohini and the experimental results showed that treatment T4 (NPK 75 percent and FYM 25 percent; 6.25 t/ha) had shown the shortest time to first flowering (49 days), and was found to be superior in terms of the number of fruits/plant (11), the length and diameter of the fruits (4.88 cm and 4.76 cm, respectively), the weight of the fruits per plant (1080 g), and the yield of fruits per ha (399.99 q/ha). Kumari and Tripathi [27] concluded that integrated nutrient management with 80 %Nitrogen, Phosphorus and Potassium, 20 % N through farmyard manure, vermicompost (50:50) and PGPR resulted into maximum fruit yield (606.51 q/ha). Experimental investigations were undertaken by Chauhan et al. [22] on the impact of varieties and integrated nutrient management on the growth and productivity of chillies (*Capsicum annuum*). The treatment receiving the recommended dose of fertiliser and vermicompost 2.5 tonnes/ha showed the shortest time to first flowering (25.7 Days After Transplanting), maximum number of fruits per plant (112.8), fruit length (10.8 cm), fruit girth (2.38 cm), fruit yield per plant (271.5 g) and fresh fruit yield of (6816 kg/ha) at 90 days after transplanting. In order to determine the impact of INM on the agronomical characteristics of the tomato (*Lycopersicon esculentum* L. cv. F1 Hybrid Arka Rakshak) in field circumstances, Chopra et al. [28] conducted an experiment in tomato. Among the various treatments, the plants that received 50% RDF and agro-residue vermicompost (ARV) at a rate of 5 t/ha showed the highest maximum number of fruits per plant (45.12) and fruit output per plant (5680.88 g). Islam et al. [29] examined the effects of organic and inorganic fertilisers on tomato growth, yield, and quality. The use of 8 tonnes of vermicompost along with N (40 kg), P (14 kg), K (24 kg), S (5 kg), Zn (0.7 kg), and B (700 g) to treat the integrated plant nutrient system resulted in the highest number of flower clusters per plant (31.28), fruit length (5.45 cm), fruit diameter (4.84 cm), and fruit yield (15.39 t/ha). According to research by Kumar *et al.* (2017) on the impact of integrated nutrient management on tomato productivity and soil health, the average tomato output in demonstration fields was between 194.50 and 215.55 q/ha, but it was between 161.85 and 172.65 q/ha in local practise. Kumar et al. [30] studied to determine the response of tomato (*Lycopersicon esculentum* Mill.) to INM and concluded that maximum fruit production (284.81 q/ha) was generated by applying 43.5 tonnes of farmyard manure and 50% of recommended dose of fertilizers produced as compared to control (198.6q/ha). A study on the integrated use of excreta-based vermicompost and inorganic nitrogen and phosphorus fertiliser, tomato fruit yield, quality, and soil fertility was carried out by Mengistu et al. [23]. The results showed that maximum fruit cluster per plant (17.07), number of fruits per cluster (3.24), number of fruits per plant (52.67), fruit diameter (42.87mm), fruit weight (62.81g), and marketable fruit yield (52.51 t/ha) were recorded in treatment combinations of 75% RDF and 11.25 ton/ha vermicompost. The impact of INM on tomato

(*Lycopersicon esculentum* L.) cv. Pusa Ruby growth, yield, and quality was examined by Rajeev *et al.* (2017). The parameters such as minimum number of days to first flowering (37.72), maximum number of clusters per plant (9.78), number of fruit per plant (15.95), fruit diameter (60.69 cm), fruit weight (68.28 g), fruits yield per plant (1.09 kg), fruit yield per plot (17.44 kg) and fruit yield (363.60 q/ha) were recorded with the combination of Recommended Dose of Fertilizers (25 %), FYM (25 %), *Azotobactor* (25 %) and *Azospirillum* (25 %). Tekale et al. [31] conducted an experiment on the effects of integrated nutrient management (INM) on the availability, uptake, and yield of tomato (*Lycopersicon esculentum* Mill.) cv. "Gujrat Tomato-2" nutrients. In two consecutive seasons and using pooled data, integrated nutrition management treatment application with FYM 20 t/ha and 100 %RDF had considerably increased maximum fruit production per plant to 1.49, 1.58, and 1.54 kg and fruit yield to 29.86, 31.56, and 30.71 kg per plot. Avhad et al. [32] studied that the response of tomato plants to INM for growth, yield, quality and nutrient uptake and the results showed that the application of Recommended dose of fertilizer 300: 150:150 NPK (kg/ha) and FYM 20 t/ha produced maximum number of fruits per plant (42.62), average weight of fruit (86.33 g) and fruit yield per plant (2.54 kg). Kumar, [33] worked on the effect of integrated nutrient management to enhance the soil fertility and crop yield of hybrid cultivar of brinjal (*Solanum melongena* L.) under field conditions. Research findings revealed that the the maximum number of fruits per plant (55.64) and crop yield per plant (6084.25g) was achieved with 50 percent of recommended dose of fertilizer and vermicompost at 5t/ha Illupeju et al. [34] investigated the effects of organic and inorganic fertilisers on three types of tomatoes (*Lycopersicon esculentum* (L.) Mill) in Ogbomoso, Nigeria. They looked at growth, fruit production, nutritional value, and lycopene concentration. The highest fruit output was 45 and 56 percent higher in Roma VF and Ogbomoso local than with other types when 50 percent NPK and 50 percent tithonia compost were applied, according to the results. To investigate the impact of organic manures and chemical fertilisers on plant growth, yield, fruit quality, and shelf life, Laxmi et al. [35] evaluated the tomato variety PKM-1 and according to the results, the combination of RDF and FYM, each at 50%, recorded the minimum days to first flowering (29.47) and the maximum number of fruits per cluster (5.67), number of fruits per plant (36.72), average fruit weight (41.67g), fruit yield per plant (849 g), fruit yield per plot (13.50 kg), and fruit yield per hectare (33.77 t/ha). The effects of integrated nutrient management strategies on the growth, yield, and economics of the green chilli cv. Pusa Jwala were assessed by Rani et al. [24]. (*Capsicum annuum* L.). The findings showed that the maximum number of fruits per plant (194 and 164), fruit yield per plant (410 and 315 g), and total green chilli yield per hectare (13306 and 10550 kg/ha), respectively, were obtained with a combined application of 150 kg of nitrogen/ha along with 10 t/ha of FYM and 0.5 t/ha of neem cake. Singh, [36] carried out a study in tomato and found that maximum number of fruit clusters (7.21), fruit weight (55.90 g) and fruit yield per hectare (26.74 mt/ha) were obtained in the treatment combination of 14.33 mt/ha farmyard manure, 7.20 mt/ha vermicompost and NPK. In an experiment on the impact of integrated nutrient management on the uptake and yield of tomato (*Lycopersican esculentum* L.), Chaitanya et al. [37] concluded that the application of 75% RDN through fertilisers and 25% RDN through vermicompost led to themaximum fruit yield per hectare (84.97 q/ha). Islam et al. [29] conducted research on the impact of integrated nutrient management on tomato growth, yield, and soil fertility. Findings showed that a mixture of 2 tonnes per hectare of poultry manure and 75 percent of RDF produced the maximum number of tomatoes (15.67), fruit diameter, yield per plant, and yield per hectare. The maximum number of fruits per plant (51.40), fruit diameter (4.90 cm), and total fruit production (30.02 t/ha) were observed by Babajide and Salami [38] in their study of the response of tomato plants to the combined application of 30 kg N/ha (urea) and 2.5 t/ha of Tithonia-compost. The impact of integrated nutrient management on soil dehydrogenase activity, nitrogen uptake, and tomato fruit yield was reported by Chaitanya et al. in [39]. (*Lycopersican esculentum* L.). The tomato plants receiving the recommended dose of nutrient fertilisers (75% inorganic fertiliser and 25% vermicompost) had the highest fruit output (84.97 q/ha). Prativa and Bhattarai [40] conducted research on the impact of integrated nutrient management on tomato growth, yield, and soil nutrient status. They reported that the application of 16.66 mt/ha farmyard manure, 8.33 mt/ha vermicompost, and NPK combination produced the maximum fruit weight (52.80 g) and fruit yield (25.74 mt/ha). Singh et al. (2010) conducted an experiment to determine the effects of vermicompost and NPK fertiliser on the morpho-physiological features of plants, yield,

and quality of tomato fruits (Solanum lycopersicum L.). The maximum fruit weight (88.9g and 93.6g) and fruit yield per plant (2.939 and 3.049 kg) were observed in T3 (NPK 60:30:30 kg/ha and vermicompost 7.50 t/ha) in both years as compared to control. Narayan et al. [26] worked on the effect of organic manures and inorganic fertilizers on fruit yield of tomato. Maximum fruit output per ha (479.43 q/ ha) was significantly increased by the application of farmyard manure (20 t/ha) and the recommended quantity of NPK (150:60:60 kg NPK / ha). Rodge and Yadlod [41] studied on the influence of organic and inorganic fertilizers on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) and reported that the maximum number of fruits per plant, fruit weight, fruit yield per plant and per plot were obtained in the treatment combination of 50 % RDF + 50 % FYM (T-8). The maximum fruit length (5.72 cm), fruit width (6.56 cm), number of fruits/plant (6.56), average fruit weight (51.98 g), and fruit yield per plant (1.158 kg) and fruit yield (368 kg/ha) were all significantly increased by the application of NPK @ 120:60:60 kg/ha, farmyard manure (10 t/ha), sulphur (25 kg/ha), Azotobacter, and mixture of all micronutrients, according to research by Singh and Singh, 2004.

1.6 Effect of Integrated Nutrient Management on Quality Parameters

In an experiment conducted in the field, Chopra et al. [28] investigated the impact of INM on the agronomical characteristics of the tomato (*Lycopersicon esculentum* L. cv. F1 Hybrid Arka Rakshak). The application of 50% RDF and agro-residue vermicompost (ARV) @ 5 t/ha produced the highest chlorophyll content (4.68 mg/g fwt) and total sugars among the other treatment combinations, according to the results. The integrated use of excreta-based vermicompost and inorganic nitrogen and phosphorus fertiliser on tomato fruit output, quality, and soil fertility was studied by Mengistu et al*.* [23] at Dire Dawa. With 75% RDF and 11.25 tons/ha of vermicompost, the highest TSS (4.89 ^{o}brix) was achieved. Rajeev et al. [42] assessed the impact of INM on the growth, yield, and quality of the Pusa Ruby variety of tomato (*Lycopersicon esculentum* L.) and reported that combining RDF with farmyard manure and adding 25% each of Azotobactor and Azospirillum produced the highest levels of acidity (0.59%), TSS (6.04), and vitamin C (27.37 mg/100g). Kumar [33] conducted research on the effects of integrated nutrient management on the soil fertility and crop productivity of a hybrid brinjal cultivar. Findings showed that among several treatments, brinjal with 50% RDF and vermicompost at 5t/ha had the maximum chlorophyll content (4.82 mg/100g) and total sugar. Ilupeju et al. [34] carried out research work on the effect of organic and inorganic fertilizers on growth, fruit yield, nutritional and lycopene contents of three varieties of tomato (*Lycopersicon esculentum* L.) in Ogbomoso, Nigeria. The highest vitamin C content 23 to 67 percent increase in Roma VF as compared with other varieties with application of 50 percent NPK and 50 percent tithonia compost. In an experiment, Laxmi et al. [35] examined the effects of organic manures and chemical fertilisers on tomato cv. PKM-1 plant growth, yield, fruit quality, and shelf life. Maximum TSS (5.0 ^{o}brix), ascorbic acid concentration (26.54 mg/100 g fruit juice), and shelf life were observed by tomato plants treated with a mixture of 50% RDF and FYM (11.67 days at room temperature). Chatterjee et al. [43] studied the use of vermicompost substitution on shelf life and fruit quality of tomato (*Lycopersicon esculentum* Mill.). Results showed that 75 percent RFD, 4 Mt/ha vermicompost and microbial amendment (22.67 days) followed by 75 percent RFD and 4 Mt/ha vermicompost (20.67 days) and 75 percent RFD, 6 Mt/ha manure, 2 Mt/ha vermicompost and microbial amendment (19.33 days) recorded maximum shelf life of tomato fruits at room temperature.75 percent RFD, 4 Mt/ha vermicompost and microbial amendment treatment shown maximum TSS (4.52 ºBrix) and total sugar (2.84%). The impact of integrated nutrient management on soil dehydrogenase activity, nitrogen uptake, and tomato fruit yield was studied by Chaitanya et al. in [39]. (*Lycopersicon esculentum* L.). The highest levels of ascorbic acid (30.83 mg/100g) and lycopene (4.05 mg/100g) were found in plants that received a mixture of 50 % vermicompost and 50 % poultry manure.

1.7 Effect of Integrated Nutrient Management on Post-harvest Soil Parameters

In a study by Kumari and Tripathi [27], the highest levels of available phosphorus (91.07 kg/ha) and potassium (285.38 kg/ha) were found in 80% NPKM + 20% N through FYM and VC (50:50) and PGPR treatment (T3) at harvest stage of the tomato crop, respectively. With the combined application of poultry manure @ 3 tonnes per hectare, rice straw @ 5 tonnes per hectare, and the recommended dose of plant

hormone in post-harvested soil sample, Islam et al. [29] found maximum soil pH (6.88), organic carbon (1.22%), total nitrogen content (0.41%), available P (20.79 g g-1 soil), and exchangeable K (0.27 cmol 100 g-1 soil. Prativa and Bhattarai [40] provided a comprehensive explanation of the nutrient status of several integrated nutrient management treatments. The application of 1/2 NPK + 15 mt/ha Vermicompost produced the highest levels of accessible nitrogen (382.80 kilogrammes per hectare), phosphorus (100.40 kilogrammes per hectare), and potash (230.80 kilogrammes per hectare) among the treatments (T5). According to Babajide et al. [38], treatment C2F2 (composted tithonia-biomass@ 5 tonnes per hectare and 60 kilogramme nitrogen in the form of urea per hectare) recorded the highest pre-cropping initial soil pH of 6.12 and the highest post-cropping soil pH (6.34). Mengistu et al. [23] carried out experimental studies on the combined application of excreta-based vermicompost and inorganic nitrogen and phosphorus fertiliser on tomato (*Solanum lycopersicum* L.) fruit yield, quality, and soil fertility and reported that maximum organic matter content (2.66%), recorded through application of zero percent RDF and 15 tonnes of vermicompost per hectare (T8), application of seventy-five percent RDF and 3.75 tonnes. Tekale et al. [31] conducted an experimental study on the effects of integrated nutrient management (INM) on the availability, uptake, and yield of tomato (*Lycopersicon esculentum* Mill.) cv. "Gujrat Tomato-2" nutrients. The application of farmyard manure @ 20 tonnes per hectare and 100% Recommended Dose of Fertilizer resulted in the maximum available nitrogen (255 and 259 kg/ha), available phosphorus (61.9 and 31 kg/ha), and available potash (327 and 322 kg/ha being observed (T1). To assess the impact of INM on tomato growth, yield, quality, and nutrient uptake, Avhad et al. [32] conducted an experiment and found that the maximum organic carbon (0.62%) was produced by using the recommended fertiliser dose (300:150:150 kg NPK) and 20 tonnes of FYM per acre (T3).

1.8 Effect of Integrated Nutrient Management on Benefit Cost Ratio

Kumar et al. [44] carried out an experiment to evaluate the response of tomato (*Lycopersicon esculentum* Mill.) to INM. They found that application of 43.5 tonnes of FYM and 50 % of RDF resulted into maximum B: C ratio (1.29). Laxmi et al. [35] conducted experiment on influence of organic manures and chemical fertilisers on plant growth, yield, fruit quality and shelf life of tomato (*Solanum lycopersicon* L.) cv. PKM-1. Findings showed that a combination of 50 % of the recommended fertiliser dosage and 50 % of farmyard manure produced the maximum B:C ratio (2.75:1). Manohar et al. [45,46] conducted an experiment on the integrated nutrient management of the Rocky variety of tomato (*Lycopersicon esculentum* Mill). Findings showed that the optimal treatment combination in terms of net yields and the B: C ratio was the application of FYM 15 t/ha together with 75 % RDF (NPK), B, and Zn. Singh and Singh [36] found that the application of NPK at the rate of 120:60:60 kg/ha, FYM (10 t/ha), sulphur (25 kg/ha), Azotobacter, and a combination of all micronutrients significantly increased the maximum benefit cost ratio to 2.40 when compared to control.

2. CONCLUSION

In conclusion, the review analysis focused on the role, significance, and management strategies for organic and inorganic nutrient sources in tomato production. In current times, India is the 2nd most populated country in the world today, has a burgeoning population and dwindling supply of arable land, resource regularly have made evident that the food needed for the growing population could be met only by increasing the agricultural production and productivity. The Integrated Nutrient Management is an alternative approach for environment friendly and cost-effective and sustainable management for improving soil fertility (health), soil productivity, quality, as well as lowering the impact of synthetic fertilizers. Combined application of inorganic and organic nutrient sources resulted in good growth, yield and quality attributes of Tomato, significantly higher yield, and controlling disease in Tomato. Therefore, it is imperative to investigate the effects of direct or combined application of organic manure, inorganic fertiliser, and biofertilizers with potential inorganic fertiliser decrease on tomato yield and quality. Finally, the findings suggested that Integrated Nutrient Management would be a good nutrient management option for Tomato.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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