

Review Article

<https://doi.org/10.20546/ijcmas.2018.706.017>

Does Integrated Sources of Nutrients Enhance Growth, Yield, Quality and Soil Fertility of Vegetable Crops?

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ABSTRACT

In order to meet the growing demand of vegetables, agricultural land per unit area required to achieve maximum efficiency and highest quality product. It is well known fact that nutrition of plant is one of the most important factors to control agricultural productivity and quality. It has been well documented that rates of nutrients in the soil affect the quality and yield of crops. Probably the soil environment is the most vulnerable to the direct effects of these practices in modern agriculture. Excessive use of inorganic fertilizers could destroy the fertility of the soil in a long run which compels the scientific community to look for the alternatives like organic farming and integrated use of organic and inorganic fertilizers. To achieve the target, integrated sources of nutrient may be useful in resolving these concerns, which has been proposed as a promising strategy for addressing these challenges. INM has multifaceted potential for the improvement of plant performance, resource efficiency and also enabling the protection of the environment and resource quality. Lower inputs of chemical fertilizer and therefore lower human and environmental costs (such as intensity of land use, N use, reactive N losses and GHG emissions) were achieved under advanced INM practices without any negative effect on crop yields. The role and importance of inorganic fertilizers in combination with organic manures and bio-fertilizers in sustainable crop growth, production, quality and soil health has been reviewed by several authors. The findings of different workers revealed that the integrated sources of nutrients increased growth, yield and quality of vegetables as compared with conventional methods as sole application of 100% recommended dose of chemical fertilizers. The results also demonstrated that the integrated sources of nutrients practices increase nutrient use efficiency and improve soil health and sustainability. Strong and convincing evidence indicates that INM practice could be an innovative and environment friendly practice for sustainable growth, yield and quality of vegetables.

Keywords

Organic manure,
Inorganic fertilizers,
Bio-fertilizers,
INM, Soil quality,
Vegetable crops

Article Info

Accepted:
02 May 2018
Available Online:
10 June 2018

Introduction

The country's horticulture production rose by 5 per cent to touch an all-time high of 300 million tonnes during 2016-17 on the back of record output of fruits, vegetables, spices and plantation crops. India is the second largest producer of vegetables, next only to China. China accounts for 45% of the global value of vegetable production and India comes second, accounting for 8% production of vegetables (FAO, 2017).

Vegetable production rose by 4 per cent in India and reached up 176 million tonnes in 2016-17 (Ministry of Agriculture and Farmers Welfare, 2017). Among vegetables, onion production rose by nearly 4 per cent to 21.7 million tonnes. Tomato output, too, grew by 4 per cent to around 19.5 million tonnes. The major onion growing and producer states are Madhya Pradesh, Andhra Pradesh, Karnataka, Odisha and Gujarat, Maharashtra and Bihar. The country witnessed record potato output at 48.2 million tonnes in 2016-17 from 43.4 million tonnes in the previous year. Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh and Punjab are major producing states.

Our demand of vegetable will be 250 million ton by 2020 AD (Singh, 2000), whereas, the expected production at present is about 160 million tonne and annually 0.8% of agricultural land being usurped for urbanization (Kar, 2002). The increase in vegetable production by increasing area under vegetable cultivation is limited due to continued decrease of land holdings. Hence, it is essential to increase vegetable productivity by application of fertilizers to fulfil country's requirements for food and nutrition security and poverty alleviation. The modernization of agriculture is one of the most important factors for increasing the use of agrochemicals. The use of chemicals in

agriculture started with the use of fertilizers. Agro-chemicals enabled man to control the plant growth and have become the greatest tool in the hand of horticulture for increasing yield and better quality vegetables.

Integrated plant nutrient management is the intelligent use of optimum combination of organic, inorganic and biological nutrient sources in a specific crop, cropping system and climatic situation so as to achieve and to sustain the optimum yield and to improve or to maintain the soil's physical, biological and chemical properties. Such a crop nutrition package has to be technically sound, economically attractive, practically feasible and environmentally safe (Hedge and Rudragouda, 2003). The program also involves maximize biological inputs to crop production and minimize the use of inorganic amendments so as to create a much more sustainable pattern of crop production, not only ecologically but also environmentally (National Research Council, 1991).

Integrated Nutrient Management in vegetable crops is very important to address the issues like poor quality of vegetables in terms of nutritional value, low yield and production. One of the factors affecting the productivity in most of the vegetable crops is improper use of nutrients. To improve the productivity, quality and soil fertility by adequate amount of fertilizers in balanced proportion should be used which has been given less attention by the vegetable growers.

Why integrated nutrient management is needed in vegetable crops?

INM is very essential to address the following issues:

The decline in productivity can be attributed to the appearance of deficiency in secondary and micronutrients.

The physical condition of the soil is deteriorated as a result of long-term use of chemical fertilizers. The recent energy crisis, high fertilizer cost and low purchasing power of the farming community have made it necessary to rethink alternatives.

Unlike chemical fertilizer, organic manure and bio-fertilizer are available locally at cheaper rates

Principles of Integrated Nutrient Management (INM)

The main principle of INM is to maximize biological potential for improving crop productivity and resources use efficiency through root zone/rhizosphere management. Plant roots take up nutrients from soils via the rhizosphere, a narrow zone of the soil that is directly influenced by root growth, root secretions, and associated soil microorganisms (Zhang *et al.*, 2012). The rhizosphere is the important interface where interactions among plants, soils, and microorganisms occur and is a “bottleneck” controlling nutrient transformations, availability, and flow from soils to plants. Therefore, the chemical and biological processes occurring in the rhizosphere determine the mobilization and acquisition of soil nutrients together with microbial dynamics, and also control nutrients use efficiency by crops, and thus profoundly influence cropping system productivity and sustainability (Zhang *et al.*, 2004, 2010, 2011, 2012). The principle of INM is to control the N losses and their harmful environmental effects, while achieving high crop productivity (Gruhn *et al.*, 2000).

The fate of N in field is an integrated consequence of crop N uptake, immobilization and residues in the soil, and N losses to the environment, such as ammonia volatilization, NOX emissions, denitrification, N leaching and runoff (Witt and Dobermann, 2004).

Advantages of INM

Enhances the availability of applied as well as native soil nutrients.

Synchronizes the nutrient demand of the crop with nutrient supply from native and applied sources.

Provides balanced nutrition to crops and minimizes the antagonistic effects resulting from hidden deficiencies and nutrient imbalance.

Improves and sustains the physical, chemical and biological functioning of soil.

Minimizes the deterioration of soil, water and ecosystem by promoting carbon sequestration, reducing nutrient losses to ground and surface water bodies and to atmosphere

Disadvantages of INM

Organic sources used in INM are comparatively low in nutrient content, so larger volume is needed to provide enough nutrients for crop growth.

The nutrient composition of compost and FYM is highly variable; the cost is high as compared to chemical fertilizers.

Integrated nutrient management system is more labourers intensive as compared to the conventional methods.

Components of INM

Organic Manures

Organic manures are valuable by-products of farming and allied industries, derived from plant and animal sources. These manures have the advantage of supplying secondary and micro nutrient along with NPK, which is

important for sustained production. The commonly used organic manures are Farm Yard Manure (FYM), Enriched Organic Manure, Vermicompost, Poultry Manure, Biogas Slurry, Urine and Liquid Manure etc.

Green manuring

Green manure crops are grown usually for restoring or enhancing soil organic matter content, properties of soil and nitrogen content in the soil and their use in cropping system is called green manuring.

Legumes are generally used as green manure crops due to their ability to fix atmospheric nitrogen in the root nodules through symbiotic association with a bacterium.

The following plants are commonly used for preparing of green manures, i.e. cowpea, dhaincha, sunhemp, karanj etc.

Biofertilizers

Biofertilizer is a substance which contains living microorganisms which, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant.

Biofertilizers can be grouped in to five categories (Barman *et al.*, 2017)

Nitrogen (N₂) fixing biofertilizers: it can be sub group in three category

Free-living- Example, *Azotobacter*, *Clostridium*, *Anabaena*, *Nostoc*

Symbiotic - Example, *Rhizobium*, *Frankia*, *Anabaena azollae*

Associative Symbiotic- Example, *Azospirillum*

P-solubilizing biofertilizers

Bacteria- Example, *Bacillus megaterium* var. *phosphaticum*, *Bacillus circulans*, *Pseudomonas striata*

Fungi- Example, *Penicillium sp.*, *Aspergillus awamori*

P-mobilizing biofertilizers

Arbuscular mycorrhiza- Example, *Glomus sp.*, *Gigaspora sp.*, *Acaulospora sp.*, *Scutellospora sp.*, *Sclerocystis sp.*

Ectomycorrhiza –Example, *Laccaria sp.*, *Pisolithus sp.*, *Boletus sp.*, *Amanita sp.*

Orchid mycorrhiza – Example, *Rhizoctonia solani*

Biofertilizers for micro nutrients

Silicate and zinc solubilizers. Example, *Bacillus sp.*

Plant growth promoting rhizobacteria

Pseudomonas. Example, *Pseudomonas fluorescens*

Different methods of integrated sources of nutrients in crops

Combined use of chemical and organic fertilizers

The integrated nutrient management system is an alternative and is characterized by reduced input of chemical fertilizers and combined use of chemical fertilizers with organic materials such as animal manures, crop residues, green manure and composts. Management systems that rely on organic inputs as plant nutrient sources have different dynamics of nutrient availability from those involving the use of

chemical fertilizers. For sustainable crop production, integrated use of chemical and organic fertilizer has proved to be highly beneficial.

Combined use of bio-fertilizers with chemical or organic fertilizers

In this system, the nutrients provided to the crops by combined use of i.e. biofertilizers, chemical fertilizers and organic materials such as animal manures, crop residues, green manure and composts.

Effect of integrated sources of nutrients on soil quality of vegetable crops

Reddy and Reddy (1999) noted significant increases in micronutrients in field soils after vermicompost applications as compared to those soils treated with animal manures. However, Khatic and Dikshit (2001) concluded that organic manures *viz.*, FYM @ 10 t ha⁻¹ and compost @ 10 t ha⁻¹ increased the available P status in clay soils. Similarly, Sharma and Raghu (2003) conducted an experiment to assess the effect of integrated sources of nutrients on soil quality. They reported that the integrated treatment containing FYM 6 t + 20 kg N + 13 kg P₂O₅ ha⁻¹ had highly sustainable for significant build up of organic carbon, available N and P status in Vertisols. Ghosh and Sarkar, (2000) revealed that treatment contains vermicompost had higher nutrients and microbial population in harvested soil. They further reported that one tonne of compost material can supply adequate nutrients i.e. 15 kg nitrogen (N), 8 kg phosphorus (P₂O₅) and 10 kg potash (K₂O) which can substitute of chemical fertilizer. The findings also demonstrated that compost application had increase the yield by 11.1 per cent with mature compost and 11.7 per cent with fresh compost when compared to fertilizer controlled plots. Bhardwaj *et al.*, (2002) reported that the application of

organics including biofertilizers improved the physico-chemical and biological properties of the soils. The microbial population varied between 4.9×10^7 to 6.6×10^7 cfu/g soils with a predominance of bacterial count under mid hill conditions. Chaudhary *et al.*, (2003) grown cabbage cv. Golden Acre under the organic manures *viz.* vermicompost (100 and 200 g/plant) and FYM (250 and 500 g/plant) as a solo or compound application and analyzed the soil properties of each treated plot. They observed that soil bulk density had decreased with all the organic treatments and the lowest value was obtained through VC @ 200 g/plant + FYM @ 250 g/plant. The highest soil organic carbon was obtained with VC @ 100 g/plant + FYM at 500 g/plant. The maximum available N was observed in VC @ 200 g/plant + FYM @ 250 g/plant, while maximum K was at VC @ 100 g/plant + FYM @ 500 g/plant. Tanwar and Shaktawat (2004) opined that application of FYM at 10 t ha⁻¹ (with and without PSB) improved the N status of soil but the P status at the end of system was less over initial status. However, Singh *et al.*, (2004) revealed that there was an increase in available nitrogen in soil after each harvest was observed. Inoculation of PSB and VAM significantly increased the availability of phosphorus in soil, with marginal decline in bulk density. Kumar *et al.*, (2006) found that application of 50 % N + 10 t FYM had significantly higher nutrient uptake (122.0, 37 and 110 kg of NPK ha⁻¹, respectively) and availability (248, 50 and 245 kg of NPK ha⁻¹, respectively) in soil. An experiments conducted by Ramesh *et al.*, (2008) to assess the effect of organic and inorganic on soil quality. The findings showed significant improvement in soil organic carbon, available N, P, K status and enzyme activity of soil (dehydrogenase and phosphatase activity) with organic manure treatments compared to chemical fertilizers alone after three year of experiments. Singh *et al.*, (2008) found that application of either cattle dung manure +

poultry manure or cattle dung manure + vermicompost + poultry manure combinations recorded significantly higher soil organic carbon (0.64 %), dehydrogenase (132 mg TPF/ kg soil / 124 h) and phosphatase (82 mg p-nitro phenol / kg soil / h) and soil microbial biomass carbon content (348 mg kg⁻¹ soil) at the end of crop cycle compared to control. Gunjal *et al.*, (2010) noticed that recommended dose of fertilizer when applied with organics *i.e.* FYM 5 t ha⁻¹ had significantly higher total uptake of N, P and K (218, 28.48 and 125.51 kg ha⁻¹, respectively) over the control (135.84, 14.66 and 82.68 kg NPK ha⁻¹, respectively). Adeleye *et al.*, (2010) analyzed the effect of poultry manure (0 t/ha and 10 t/ha) on physico-chemical properties of soil in Ondo, Nigeria. The findings indicated that poultry manure application improved soil physical properties, increased total porosity and soil moisture retention capacity. The same treatment also reduced soil bulk density and temperature. The treatment consisting poultry manure (0 t/ha and 10 t/ha improved soil organic matter, total N, available P, exchangeable Mg, Ca, K and lowered exchange acidity. Therefore, the use of poultry manure in crop production was recommended and suggested that it will ensure stability of soil structure; improve soil organic matter status and nutrients availability. Incorporation of organic fertilizers can also increase microbial activity in soils between 16 % and 20 % as compared to inorganic fertilizers (Gonzalez *et al.*, 2010). Ceronio *et al.*, (2012) reported that compost and organic manure seemed to improve the chemical properties of soil more than chicken manure. Kumar, (2012) studied the effect of integrated nutrient management on soil health and productivity of potato (*Solanum tuberosum* L.) under rainfed condition. The results showed that 50 % of the recommended dose of NPK through inorganic + 50% recommended dose of nitrogen (RDN) through organic manures (FYM, PM or VC) or 100% recommended dose of NPK through

inorganic fertilizers alone favorably influenced the tuber yield, nutrient uptake, soil fertility and paid higher returns compared to other treatments. Seed treatment with *Azotobacter* + PSB proved better in tuber yield, nutrient uptake and recorded higher returns as compared to sole treatment of either *Azotobacter* or PSB. Total organic carbon (TOC), soil microbial biomass carbon (SMBC), available N, P, and K status of the soil after 3 years were maximum when 50 % recommended dose of NPK were applied through inorganic and remaining 50 % RDN through PM. Dey *et al.*, (2015) studied the effect of different levels and combinations of organics *viz.* crop residue, bio-fertilizer, FYM alone and in combination with chemical fertilizers *viz.*, 0, 50, 100 and 150% of recommended dose of fertilizer (RDF) were tested. The mean effect of different organic treatments on improvement of soil physical properties were nearly similar the treatments containing 50% organics + 50% inorganic (INM). However, Avhad *et al.*, (2016) conducted a study to determine the influence of organic and inorganic fertilizers on soil quality parameters of tomato hybrid Phule Raja. The residual soil fertility in respect to organic carbon was improved significantly by various treatments. The integrated treatment consisting RDF 300:150: 150 kg NPK and 20 t FYM ha⁻¹ increased the organic carbon (0.62 %), total nutrient uptake of nitrogen (98.50 kg ha⁻¹), phosphorus (49.70kg ha⁻¹), potassium (123.30 kgha⁻¹), Fe (201.94 mg kg⁻¹), Mn (39.50 mg kg⁻¹), Cu (46.13 mg kg⁻¹) and Zn (51.67 mg kg⁻¹). Kumar, (2016) reported that different treatments showed significant variations in soil quality *i.e.* (P<0.05/P<0.01) EC, OC, TKN, PO₄³⁻, Na⁺, K⁺, Ca²⁺, Mg²⁺, Cd, Cr, Cu, Fe, Mn and Zn of the soil. All the treatments were recorded to be effective to increase the macro and micro essential nutrients in the soil in comparison to control. Among all the treatments, the most increase of EC, OC, TKN, PO₄³⁻, Na⁺, K⁺, Ca²⁺, Mg²⁺,

Cd, Cr, Cu, Fe, Mn and Zn of the soil was recorded with 50 % RDF + vermicompost @ 5 t ha⁻¹. Kumar *et al.*, (2017) assessed the effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation. The results of the study indicated that there was the improvement in soil biological properties and soil enzymes in all plots over the initial value. The highest biological properties like Microbial Biomass Carbon (MBC) (244.86 µg g⁻¹), bacterial population (8.24 log cfug⁻¹ soil), fungal population (3.89 log cfu g⁻¹ soil), soil enzymes like fluorescein di-acetate (FDA) (7.28 µg fluorescein g⁻¹ soil h⁻¹), phosphomonoesterase (PME) (50.15 µg p-nitrophenol g⁻¹ h⁻¹), Deydrogenase (DH) (136.90 µg TPF g⁻¹ soil 24 h⁻¹), Arylsulphatase (14.16 µg p-nitrophenol g⁻¹ h⁻¹) and Arylesterase activity (113.92 µg p-nitrophenol g⁻¹ h⁻¹) found in the treatment when plants were treated with 50% recommended dose of N, P, K + Vermicompost @ 2 t ha⁻¹ (mixed with microbial consortium). Increased in microbial population and soil enzymatic activity is the indicator of good soil condition for crop growth. Therefore, the addition of organic manure and biofertilizers along with the reduced amount of inorganic fertilizers should be advocated for maintaining high soil quality for longer the period. While, Tekale *et al.*, (2017) conducted two year trails to study the effect of Integrated Nutrient Management (INM) on availability of nutrients in soil, nutrient uptake and yield of tomato (*Lycopersicon esculentum* Mill.) cv. Gujarat Tomato-2. The results of two year experiment and their pooled data indicated that integrated treatments consisting FYM 20 t ha⁻¹ + 100 % RDF had significantly the highest available N (255, 259 and 257 kg ha⁻¹), P₂O₅(63.5, 61.9 and 62.7 kg ha⁻¹), K₂O (327, 322 and 325 kg ha⁻¹) nutrient in soil after harvest, N (1.54, 1.56 and 1.55 %), P₂O₅ (0.49, 0.50 and 0.50 %), K₂O (1.30, 1.33 and 1.32 %) nutrient content in tomato plant, total nutrient uptake N

(136, 145 and 140 kg ha⁻¹), P (45.2, 49.8 and 47.5 kg ha⁻¹), K (66, 76 and 71 kg ha⁻¹), fruit yield plant⁻¹(1.49, 1.58 and 1.54 kg) and fruit yield plot⁻¹(29.86, 31.56 and 30.71 kg).

Effect of integrated sources of nutrients on quality of vegetables

Chinnaswami and Mariakulandai, (1966) conducted an experiment to assess the influence of organic and inorganic manures on the firmness and storage life of tomato. The findings revealed that combined application of FYM and inorganic mixture increased the ascorbic acid and protein content as compared with groundnut cake and inorganic fertilizer alone. They also observed the keeping quality and storage life was better with combined application of FYM and inorganic mixture. Sujatha and Krishnappa, (1995) reported that the highest starch, crude protein and reducing sugars as well as total sugars with 120: 100: 120 kg NPK ha⁻¹ + 50 t FYM. While, Lisiewska and Kmiecik, (1996) reported that increasing the amount of nitrogen fertilizer from 80 to 120 kg ha⁻¹ decreased the vitamin C content by 7 % in cauliflower. It means organic treatment can increase the yield and quality of crop. According to Mahendran and Kumar, (1997), the size and net weight of cabbage could be significantly influenced with the application organic manures. Highest TSS and ascorbic acid contents were observed with 75 % of the recommended rate of NPK integrated with digested organic supplement and vermicompost. However, the results of Kumaran *et al.*, (1998) showed that a combination of organic and inorganic fertilizers gave the best results in terms of yield in tomato. The quality parameters such as TSS and ascorbic acid contents were comparatively higher in organically grown tomato plants. An experiment conducted by Mahendran and Kumar, (1998) to evaluate the effect of inorganic with biofertilizers on cabbage. Maximum starch and crude protein

content obtained from the plants treated with 100% recommend dose of NPK with combination of *Azospirillum* and *Phosphobacterium*. Nanthakumar and Veeraragavathatham, (1999) reported that combined application of FYM, *Azospirillum* and phosphobacteria + inorganic fertilizers favourably influence the keeping quality of brinjal with respect to lower cumulative physiological loss in weight, improved general appearance and overall high acceptance over application of inorganic fertilizer alone. Lee and Kadeer, (2000) also reported that nitrogen fertilizers at high rates tend to decreased the vitamin C content in many vegetables. Raj and Kumari, (2001) observed that combined application of FYM and neem cake (1:1) produced lower crude fibre content and best keeping quality in okra fruits. However, maximum crude protein content (17.95 %), minimum crude fibre content (12.58 %) and best keeping quality (5.68 days) obtained by application of organic manures and *Azospirillum* inoculation. Likewise, Harikrishna *et al.*, (2002) recorded the highest fruit yield (54.32 t ha⁻¹) with the application of 25 t FYM ha⁻¹ + 75% N + 100 % P + 100 % K. Similarly, Patil *et al.*, (2004) noticed the maximum number of fruits, heaviest fruit yield plant⁻¹, yield plot⁻¹, TSS and ascorbic acid contents in tomato under the treatment of 50 % RDF + 50 % FYM. Kamili *et al.*, (2002) assessed the fruit quality of brinjal (*Solanum melongena* L.) when plants treated with microbial inoculants and chemical fertilizers. The findings reported that the application of *Azospirillum* +100 kg N/h resulted maximum vitamin C' content in brinjal fruits. In case of organically managed soil, plants are generally exposed with comparatively lower amount of nitrogen and several plant nutrients are released slowly over time. Therefore, organic crop would be expected to maintain higher vitamin 'C' and carbohydrates and less protein as reported by Bahadur *et al.*, (2003) in broccoli. Kadalag *et al.*, (2007) worked on

yield and quality of tomato fruits as influenced by bio-fertilizers. The studied data exhibited that application of recommended dose along with *Azotobacter* recorded higher quality parameter of tomato such as TSS (6.23 °B), reducing sugar (2.89), acidity (0.63), vitamin C (15.2 mg/100 g) and lycopene (mg/100 g) as compared to other treatment. Wang *et al.*, (2010) observed significantly higher contents of vitamin C, phenols and flavonoids when Chinese cabbage cultivated in plastic pots filled with the vermicompost: soil mixtures with ratios the 4:7 and found 5.8- fold higher than that of full soil treatment. Toor *et al.*, (2010) used different types of fertilisers and observed the decreased in vitamin C content of tomatoes by high NO₃⁻ levels. An experiment conducted by Azin and Dhuma, (2012) to study the effect of organic manure on growth, yield and quality of tomato. The results indicated that the amendment of organic manures like Neemcake (2 kg) and Jeevamrutha (cow dung 10 kg + jaggery 2 kg + cow urine 5 liter) found to be highly significant to improve growth and yield attributes. The nutrient quality of analysis indicated the superiority of organically grown tomato in terms of total carbohydrates, proteins and vitamin C. The findings confirmed that the treatment of organic manures had positive influence on growth and yield attributes of tomato over inorganic fertilizers. Mitova *et al.*, (2014) studied the influence of organic, mineral and organic mineral fertilization on the growth, development, yield and some quality indicators for early potatoes. The highest yield (32.42 t ha⁻¹) was obtained under the mixed fertilization regime. As regards quality indicators, the biggest tubers (101.42 g tuber⁻¹) were obtained under the mixed fertilization regime with high content of total sugars - 5.1%. Shree *et al.*, (2014) found maximum ascorbic acid (63.12) when plants were grown under the treatment containing ½ N: P: K (recommended doses of NPK+ FYM 5t/ha +

poultry manure 2t/ha+ *Azospirillum* in cauliflower. Similar results were also reported by Singh *et al.*, (2014) who found maximum TSS (4.97 °B) and reducing sugar contents with the application of 100 per cent N from Poultry manure followed by, 100 per cent from vermicompost (10 t ha⁻¹). Avhad *et al.*, (2016) conducted a study to determine the influence of organic and inorganic fertilizers on quality parameters of tomato hybrid Phule Raja. The findings exhibited non-significant effect on parameters viz., TSS, acidity, total sugars, reducing sugars, non-reducing sugars, sugar: acid ratio etc. Nurhidayati *et al.*, (2016) used the vermicompost prepared from the mixture of cow manure and vegetable residue combined with inoculation of earthworm *P. corethrurus* by 0-25 indiv m⁻². The treatment had the highest contents of vitamin C with increase of 12%. The vermicompost consisting the mixture of cow manure and leaf litter combined with inoculation of earthworm *P. corethrurus* by 25-50 indiv m⁻² had the highest sugar content, with increase of 57% compared to the inorganic treatment. While, Goswami *et al.*, (2017) reported that use of VC and DC in combination with recommended chemical fertilization effectively stimulated crop growth, yield, product quality, and storage longevity for both tomato and cabbage. Sachan *et al.*, (2017) studied the quality parameters of Okra (*Abelmoschus esculentus* L.) as influenced by the integrated nutrient management. The results revealed that the plants treated with NPK @ 75% + FYM @2.5tn/ha + Poultry manure @2.5tn/ha + Vermi- compost @2.5tn/ha significantly exhibited maximum protein content (16.61%) and TSS (2.44°Brix) as quality parameters while the treatment control showed lowest response. Kiraci, (2018) used cow manure, sheep manure, poultry manure, seaweed, and conventional applications to assess the effect on growth and quality of carrots. The findings revealed that five-ton poultry manure application gave the

highest (5.91 t/ha⁻¹) whereas, control application was the lowest (3.37 t/ha⁻¹). The widest root diameter, longest root length, the highest root weight, total soluble solids content, total sugar content, antioxidant activity were determined in different doses of poultry manure applications. A correlation between the examined quality and plant characteristics was determined. The other the most dry matter (11.80%), phenolic matter (188.98 mg.10⁻² microgram/g GAE) and b carotene (205.95 mg.g⁻¹) contents was determined in conventional application. The different doses poultry manure application on growth and yield of carrot were determined a positive effect.

Effect of integrated sources of nutrients on growth and yield of vegetable crops

Onion

Singh *et al.*, (1997) investigated the effects of different organic manures and inorganic fertilizers on the yield and quality of Rabi onion (cv. Agrifound Light Red). The findings revealed that farmyard manure produced the highest gross and marketable yields of onion. The similar findings had been observed by Yadav and Yadav, (2001) who reported that the recommended FYM + NPK significantly produced highest bulb yield (370.39 q ha⁻¹). Another study carried out by Alkaff *et al.*, (2002) who obtained the larger size bulb (44 %) with mineral fertilizer, followed by, the biofertilizer and FYM. The highest yield/ha⁻¹ (21.76 %) was recorded with FYM, followed by, the mineral fertilizer and biofertilizer. Reddy and Reddy, (2005) studied the effect of different levels of vermicompost (0, 10, 20 and 30 t ha⁻¹) on growth of onion (cv. N-53). The results revealed that treatment containing vermicompost from 10 to 30 t ha⁻¹ significantly increased plant height, number of leaves per plant and leaf area. Patil *et al.*, (2005) assessed the effect of flyash and FYM

on nutrient uptake and yield of onion. The results indicated that with increasing levels of FYM (0, 5, 15 and 30 t ha⁻¹), significantly increases the uptake of N (ranging from 0.08 to 0.13 g/plant), P (ranging from 0.12 to 0.15 g/plant) and K (ranging from 0.61 to 0.92 g/plant) by onion bulb besides increasing onion yield. Jayathilake *et al.*, (2006) reported that the application of vermicompost alone had significantly produced higher bulb yield (18.8 t ha⁻¹) than the sole application of FYM or combined application of FYM and vermicompost. An experiment carried out by Dimri and Singh, (2006) to assess the effect of FYM on onion bulb yield. The results indicated that application of FYM @ 15 t ha⁻¹ produced the highest bulb weight, *i.e.* 74.45 g with the total onion yield of 291.02 q ha⁻¹. Similar results were observed by Lal and Khurana, (2007) who reported that application of FYM @ 20 t ha⁻¹ increased the onion bulb yield as compared than RDF in potato-onion-guar sequence rotation. The results were close conformity with the results of Ansari, (2008) who investigated the effect of vermicompost and vermiwash in reclaimed sodic soils on the productivity of onion. The findings revealed that the yield of onion was significantly higher in plots treated with vermiwash (1:10 v/v in water), whereas the average weight of onion bulbs was significantly greater in plots amended with vermicompost and vermiwash (1:5 v/v in water). Yephtho *et al.*, (2009) observed maximum P content in leaf (0.34 %) and bulb (0.46 %) when plants were treated with Vermicompost + *Azotobacter*. Prabhakar *et al.*, (2012) evaluated the growth and yield of onion treated by organic manure and inorganic nutrients. The treatment received 100 % recommended N, equivalent through organics produced the highest yield of 21.06 t ha⁻¹, plant height and leaf area index. However, Lee, (2012) found that the application of cattle manure compost improved yield of intermediate-day onion and soil fertility under reduced rates of chemical

fertilizer. The results also demonstrated that CMC (cattle manure compost) application over 40 Mg ha⁻¹ (1 Mg ha⁻¹ = 0.4461 t acre⁻¹) did not exhibit the effect in onion bulb yield but accumulated soil nutrients in the plants. Kaswan *et al.*, (2013) had the maximum number of leaves per plant, plant height, fresh weight of bulb, diameter of bulb, volume of bulb, bulb yield, TSS and pungency with the application of FYM @ 40 t ha⁻¹. In the field trial conducted by Gopakkali and Sharanappa, (2014) to study the effect of different organic treatments on growth and yield of onion. The findings exhibited that the application of enriched bio-digested liquid manure (EBDLM) @ 100 kg N equivalent/ha + 3 sprays of panchagavya (3%) recorded the highest plant height (42.3 cm), leaves/plant (8.1), leaf diameter (1.46 cm), fresh weight of bulb (143.7 g), bulb yield (42.8 t ha⁻¹), neck diameter (1.42 cm), bulb diameter (6.02 cm), bulb length (5.36 cm), total soluble solids (14.4 °B). Moradi, (2015) observed that the application of sheep manure (5 t ha⁻¹) increased fresh weight, dry weight, plant volume, bulb diameter, bulb height and plant height as compared to control. Talwar *et al.*, (2016) assessed the effect of different combinations of bio-fertilizer along with inorganic fertilizers and organic manures on growth, yield and quality of onion during kharif season. The results revealed that the number of leaves per plant, plant height and leaf area was maximum with the application of *Azotobacter* along with recommended dose of fertilizers. Minimum neck thickness was recorded in treatment where *Azospirillum* was applied along with recommended dose of fertilizers. Likewise, the *Azospirillum* produced the maximum bulb weight 138.3g and total yield 299.6 q/ha when it was applied with recommended dose of fertilizer. However, maximum bulb diameter was recorded when plants were treated with *Azotobacter* along with recommended dose of fertilizers. Prabhakar *et al.*, (2017) studied the

effect of different levels of farm yard manure (FYM) in organic as compared to chemical and conventional practices on growth, yield and quality of onion. The findings indicated that the plants received organic manure equivalent to 100 per cent recommended dose of nitrogen (RDN) had highest number of leaves (10.5) per plant. The bulb yield was on par with the yields obtained in organic treatments receiving FYM equivalent to 50 to 100 per cent RDN. The lower bulb yields were observed with organic treatment receiving manures equivalent to 25 per cent RDN and treatment receiving only NPK fertilizers. Singh *et al.*, (2018) evaluated the effect of organic farming on yield, yield parameters and storage quality of onion (*Allium cepa* L.) in Rabi season. The results exhibited that the treatment contains, RDF + organic source gave maximum total bulb yield (258.38 q/ha) followed by, vermicompost @ 15 t/ha and by Farm Yard Manure @ 30 /ha with (237.38 q/ha) and (222.65 q/ha) respectively. In case of marketable bulb yield, the plants treated by INM (RDF + organic source) followed by, Vermicompost @ 15 t/ha gave maximum marketable bulb yield (250.02 q/ha) and (230.01 q/ha) respectively. Maximum cost benefit ratio was found in the treatment, treated by RDF + organic source followed by, Vermicompost @ 15 t/ha with (2.61: 1) and (2.34: 1) respectively. Minimum total storage losses were recorded when plants were received Vermicompost @ 15 t/ha with (71.25 %) which was best from rest treatments during investigation. However, maximum dry matter yield gave by Poultry manure @ 15 t/ha.

Cabbage

Kanwar and Paliyal, (2005) observed a net saving of 50 % of synthetic fertilizer by substituting vermicompost for FYM along with 100 % NPK. Kumar *et al.*, (2008) analyzed the different integrated nutrient managements on the growth parameters in

cabbage (*Brassica oleracea* L.var. Capitata). The findings revealed that the treatment consisting 80 kg N + 80 kg P₂O₅ + 60 kg K₂O + 20 kg ZnSO₄ + VC 5 t/ha followed by 100 kg N + 80 kg P₂O₅ + 60 kg K₂O + 20 kg ZnSO₄ + FYM 10 t/ha as the best in respect to higher values for growth attributing parameters in cabbage. Similar findings were observed by Devi and Roy, (2008) who conducted an experiment to study the effect of different integrated combinations on growth and economic yield of cabbage. The integrated treatment consisting 120 N, 100 P and 120 K kg/ha + 25t FYM/ha + *Azotobacter* 2kg/ha + *Phosphotika* 2Kg/ha recorded maximum of yielding parameters like diameter (15.37 cm and 14.69 cm for polar diameter and equatorial diameter, respectively) and consequently the yield (34.11 t/ha) and net profit as well. As application of 60 N, 100 P, 120 K kg/ha + 25 t FYM/ha + *Azotobacter* 2 kg/ha + *Phosphotika* 2 kg/ha yielded at par with N 120 kg/ha, P 100 kg/ha, K 120 kg/ha + 25 t FYM/ha (without biofertilizers). It showed that biofertilizers could result in a net saving of 50 % of nitrogen. Sarangthem *et al.*, (2011) obtained significantly highest yield of cabbage (17.89 t/ha) with the combined application of vermicompost @ 3 t/ha and *Azospirillum* vis-a-vis sole application of FYM @ 3 t/ha. The concentration of nutrients like (NPK) in shoot and root of cabbage were also higher in the treatment receiving vermicompost @ 3 t/ha along with *Azospirillum* as compared to FYM treatments. Chatterjee *et al.*, (2012) revealed that cabbage head yield and its shelf life; TSS, vitamin A and vitamin C contents were significantly influenced by the application of organic manures and biofertilizers. Vermicompost which emerged as better organic sources of nutrient over farmyard manure. Inoculation with *Azophos*, a commercial biofertilizer preparation containing the *Azotobacter* and PSB exerted more positive result over uninoculated treatments and benefits of

biofertilizer application were more in presence of vermicompost as compared to farmyard manure. However, Merentola *et al.*, (2012) obtained the maximum head yield (56.37 t/ha) with 50 % NPK + 50 % FYM + biofertilizers which was significantly superior over other treatments except 100 % NPK, 50 % NPK+50 % Pig manure + biofertilizers and 50 % NPK + 50 % vermicompost + biofertilizers, where values of head yield were 49.38 t/ha, 50.56 t/ha and 53.64 t/ha, respectively. Singh *et al.*, (2015) concluded that combined application of NPK @ 200:100:100 Kg/ha along with seedling treated with *Azospirillum* gave significantly higher plant height (30.40cm), plant spread (54.50cm), head diameter (24.32cm), head depth (21.71cm), head weight (1.878 Kg) and head yield (868.70 q/ha) while, days taken to head formation and head maturity, number of outer leaves/plant and number of inner leaves/head did not show significant interaction effects. Jha *et al.*, (2017) studied the effect of organic, inorganic & biofertilizers on growth attributes of cabbage (*Brassica oleracea* var. *Capitata*).

The results showed that maximum head formation was recorded (95.01%) with 75 % RDF + 25 % N through FYM and the treatment consisting FYM+VC+AZ+PSB had (78.41 %) at harvesting stage. Maximum head height was recorded 60 DAT and time of harvest are 16.91cm and 20.79 cm under treatment 75 % RDF + 25 % N through FYM, while minimum head height was recorded 12.43 cm and 14.71cm under treatment 75 % RDF + 25 % N through VC and 100 % RDF + 25% N through FYM. Maximum head diameter was recorded 60 DAT and time of harvest are 42.65 cm and 46.37 cm under treatment 75 % RDF + 25 % N through FYM minimum head diameter was recorded 24.90 cm and 32.69 cm under treatment 100 % RDF + 25% N through VC and 50 % RDF + 50 % N through FYM.

Tomato

Balasubramanian *et al.*, (1998) assessed the effect of organic and inorganic nutrients on the yield and uptake of tomato (*Lycopersicon esculentum*) in Alfisols. The findings showed that organic and inorganic nutrients in combined form recorded the highest tomato yield, dry matter production content and uptake of nutrients and the residual soil fertility. An experiment conducted by Natarajan *et al.*, (2004) to assess the effect of organic and inorganic fertilizers on growth and yield of tomato. Integrated treatment consisting of 50 per cent RDF (100:50:50 NPK kg ha⁻¹) per cent + FYM 12.5 t ha⁻¹ resulted in highest vegetative growth and yield (586.51 q ha⁻¹). Similar findings were also reported by Madalageri *et al.*, (2006) who had reported that treatment receiving RDF (115:100:60 kg NPK ha⁻¹) along with FYM 25 t ha⁻¹ recorded higher keeping quality (18.5 days) of tomato cv. Megha at room temperature. However, Sudhakar and Purushotham, (2008) concluded that application of 75 per cent RDF (150:60:80 NPK kg ha⁻¹) and bio-fertilizer PSB (15 kg ha⁻¹) resulted in higher yield parameter like number of fruits per plant (25.75 g), yield per plant (751.8 kg) and yield (75.10 t ha⁻¹) of tomato. Similarly, Mahato *et al.*, (2009) recorded maximum shoot length (35.5cm), number of leaves per plant (5.6), root length (7.8 cm) with *Azotobactor* (2 kg ha⁻¹) along with 50 per cent RDF (150:50:50 kg ha⁻¹) during the raising of seedlings in nursery in tomato as compared to other treatments. While, Premshekhhar and Rajashree, (2009) found the maximum plant height (72.60 cm), number of fruits per plant (33.70) and fruit yield (43.85 t ha⁻¹) with application with *Azospirillum* (2 kg ha⁻¹) + 75per cent Nitrogen + 100 per cent P and K as compared to other treatments in tomato. Prabhu *et al.*, (2010) studied the effect of organic fertilizer on rhizosphere, growth and yield of tomato. The

findings revealed that application of RDF (120:60:60 kg ha⁻¹) along with vermicompost (5 t ha⁻¹) produced maximum growth and yield parameters like plant height (88.0 cm), fruit weight (65.8 g), fruit yield per ha (60.68 t ha⁻¹) in tomato. However, Sharma *et al.*, (2010) reported that the combined application of seedling dip with *Azotobacter* 2 kg ha⁻¹ + 75 per cent N + full dose of PK + full dose of FYM (25 t ha⁻¹) significantly increased growth, yield and quality characters over RDF or organic manures alone there by a saving of 25 per cent chemical nitrogen application during the year of study. The same treatment also found superior in terms of maximum net returns Rs. 1, 48, 089/- and highest cost: benefit ratio of 1:2.51 in tomato. Another experiment carried out by Yeptho *et al.*, (2010) who reported that integrated application of 50 per cent NPK + 50 per cent poultry manure + bio-fertilizer gave maximum plant height (164.33 cm), number of branches per plant (12.26), number of laves per plant (58.19), number of fruits per plant (33.27), fruit yield (77.54 t ha⁻¹) and TSS content (6.67 °Brix) over the other treatments in tomato. While, Prativa and Bhattarai, (2011) observed maximum plant height and number of leaves per plant with integrated treatment consisting 16.66 t ha⁻¹ FYM + 8.33 t ha⁻¹ vermicompost + NPK. The highest number of fruit clusters, maximum fruit weight and fruit yield (25.74mt ha⁻¹) were also recorded in the same treatment in tomato crop. Abul *et al.*, (2012) checked the effect of *Trichoderma*-enriched bio-fertilizer for enhance the production and nutritional quality of tomato (*Lycopersicum esculentum* L.) and minimizes NPK fertilizer. The findings reported that application of *Trichoderma* 2 kg ha⁻¹ and RDF (100:50:60 kg ha⁻¹) had maximum flowers per cluster (9.86), number of fruits per plant (25.66), maximum fruit weight (64.35 g) and yield per ha (56.30 t ha⁻¹) as compared to control (100:50:60 kg ha⁻¹) while, all yield parameters were found minimum under control in tomato. Similar

findings were also reported by (Manjural *et al.*, 2012) who reported that application of 50 per cent nitrogen along with 50 per cent *Trichoderma* enriched bio-fertilizer showed higher plant height (71.17cm), number of branches per plant (8.025), leaf area (69.73 cm²), number of clusters per plant (7.15), number of fruits per plant (41.03), fruit yield per plant (1.41 kg per plant) and fruit yield per hectare (156.36 q ha⁻¹) in tomato crop. Kumar *et al.*, (2014) reported that application of PSB at 2 kg ha⁻¹ results in maximum plant height (39.50 cm), higher number of branches per plant (6.93) and number of cluster per plant (9.83) as compared to *Azospirillum* 2kg ha⁻¹ while, all growth parameters were found minimum under control in tomato. Singh *et al.*, (2014) conducted an experiment to evaluate the effect of different combinations of organic manure and chemical fertilizers on growth of tomato. The findings reported that integrated treatment consisting 50 per cent N from inorganic sources + 50 per cent N from FYM gave the maximum yield (21.5 t ha⁻¹) and its contributing characters such as number of yield per plant (1.93 kg/plant), fresh and dry weight of fruit (177.07 g/fruit) followed by 100 per cent from inorganic source. Avhad *et al.*, (2016) conducted a study to determine the influence of organic and inorganic fertilizers on growth yield and quality parameters of tomato hybrid Phule Raja. The results revealed that there was significant influence of combined use of organic and inorganic fertilizers on growth parameters, yield contributing characters and nutrient uptake. The integrated application containing RDF 300: 150:150 kg NPK and 20 t FYM ha⁻¹) gave highest value of plant height (147.00cm), number of fruits per plant (42.62) and average weight of fruit (86.33 g) yield per plant (2.54 kg/ pl). Islam *et al.*, (2017) concluded that integrated plant nutrient system (IPNS) or mixed fertilizers containing (organic 2/3 + inorganic 1/3) produced higher number of fruits per plant (73.7) and plant

height (73.5 cm). The results also demonstrated that fruit yield and diameter were found statistically significant. No significant difference was observed in the quality (total soluble solids) of tomato fruits in both varieties' response to the treatments. The electrical conductivity and pH of the soil were improved by the application of organic manure. Kumari and Tripathi, (2018) conducted an experiment to assess the influence of integrated nutrient management on yield and uptake of tomato (*Solanum Lycopersicum* L.) and availability of nutrients in soil under mid hill conditions. The results indicated that integrated treatment consisting 80% NPKM + 20% N through FYM and VC (50:50) + PGPR had significantly the highest uptake of N (97.81 kg/ha), P (25.08 kg/ha), K (55.94 kg/ha). Fruit yield (606.51 q/ha) of tomato were also highest in 80% NPKM + 20% N through FYM and VC (50:50) + PGPR whereas, interaction effect between treatment and year (T×Y) revealed a non-significant effect, while treatment (T) showed significant effect under tomato crop. The highest available N (404.50 kg/ha) P (91.07 kg/ha) K (285.38 kg/ha) was observed under 130% NPKM (50:50 of FYM and VC as per N content).

Okra

Prabhu *et al.*, (2002) studied the effect of integrated nutrient management on fruit yield of okra. The results indicated that treatment consisting 75% NPK+FYM+ *Azospirillum* + VAM produced the highest yield. Similar findings were also observed by Tripathy *et al.*, (2004) who reported that the integrated application of 75% recommended dose of fertilizer (90:60:40 kg NPK/Ha) + Vermicompost at 5 t/Ha significantly gave higher marketable fruit yield (91.75 q/Ha) over the control and other treatments. Ray *et al.*, (2005) reported that the application of *Azospirillum* or *Azotobacter* supplemented

with 15 t FYM/Ha and 25:15.5:12.5 kg/ha NPK in okra was more beneficial for sustaining higher growth and yield of crop and promoting inherent fertility status of soil in medium land of Dankuni basin. However, Prabhu *et al.*, (2006) concluded that the combination of full RDF at 100:50:50 NPK kg/ha + FYM at 10 t/Ha + *Azospirillum* + VAM gave the maximum seed yield and seed qualities in okra. Tripathy *et al.*, (2008) examined the effect of integrated nutrient management on survivability of different diseases and fruit yield in okra. The findings reported that application of 50% RDF + BF + organic manure in the form of neem cake or vermicompost significantly reduced jassid (4.02 – 4.50 / 3 leaves) YVMV (11.70 – 13.09%) and fruit borer (5.53 – 6.13%) and recorded higher fruit yields of 83.03 to 85.51 q/ha. Bairwa *et al.*, (2009) observed that application of 60% recommended dose of NPK through inorganic fertilizer + neem cake at 0.6 tonne/ha + Vermicompost at 1 ton/Ha + *Azotobacter* + PSB resulted in significantly maximum plant height at 90 DAS (77.80 cm), stem base diameter (2.25 cm), total fruit bearing nodes/plant (19.18), number of fruit (18.36/plant), fruit weight (17.65 g), length of fruits (12.26 cm). The results also demonstrated that the same treatment was also found superior in terms of fruit yield increased (29.30%) along with highest B: C ratio (3.19) while, Tripathy and Maity, (2009) observed that the application of 50% RDF + BF + organic manure in the form of neem cake @ 1.25 t/ha or vermicompost @2.5 t/ha significantly not only increased per plant yield (408.54 g) but also quality of fruit. Kumar *et al.*, (2013) studied the integrated effect on growth and yield of okra. The findings revealed that the plant received 75kg N +40 kg P₂O₅ + 40 kg K₂O + 5 tones VC + 20 Kg ZnSo₄/ha gave the maximum growth and yield. The same treatment was also found superior in terms of gross income Rs. (58600), net return Rs. (25677) and cost: benefit ratio.

Similar findings were also reported by Ghuge *et al.*, (2015) who stated that integrated treatment consisting 75% NPK+ FYM+PSB + *Azotobacter* produced maximum plant height (118.17 cm), number of leaves (36.6), number of internodes (16.9), length of 2nd internode (112.7 cm), germination percentage (88.37%), dry fruits per plant (17.73), seed yield (9.7 q/ha), length of dry fruit per plant (16.93 cm), diameter of dry fruit (18.33 mm), 1000 seed weight (26.63 g), weight of seed per plant (77.84 g) and minimum day's for fruit maturity (87.27 days). The maximum stem diameter (19.27 mm) was recorded with application of 125% NPK. The minimum days required for flower bud initiation (34.47days), flower opening (36.4 days), fruit initiation (37.33 days) were recorded with the application of 100% NPK. However, maximum number of branches (3.2) and graded seed percentage (97.85%) were recorded with 50% NPK+ FYM + PSB + *Azotobacter*. Choudhary *et al.*, (2015) assessed the impact of bio-fertilizers and chemical fertilizers on growth and yield of okra (*Abelmoschus esculentus* L. Moench). The findings demonstrated that the integrated treatment receiving *Azospirillum* 5 kg ha⁻¹ + RD NPK significantly produced maximum plant height (96.03cm), pod weight (11.53 g), girth of pod (4.88 cm), yield plant⁻¹ (139.39 g) and yield ha⁻¹(10324.94 kg). The plants treated with PSB 5 kg ha⁻¹ + RD NPK through chemical fertilizers had the highest length of pod (12.03 cm). Whereas, the plants treated with VAM 15 kg ha⁻¹ + 75% P + 100% NK through chemical fertilizers had the highest number of pods per plant (13.11). Sachan *et al.*, (2017) evaluated the growth, yield and quality of okra (*Abelmoschus esculentus* L.) as influenced by the integrated nutrient management. The results revealed that the plants treated with NPK @ 75% + FYM @2.5tn/ha + Poultry manure @2.5tn/ha + Vermi- compost @2.5tn/ha significantly found best among the all treatments at all successive

growth stages in almost all the traits i.e. plant height (154.0 cm), number of branches per plant (4.91), fresh weight of plant (17.11t/ha) and dry weight of plant (2267.67kg/ha) as growth parameters; whereas no. of pods per plant (12.44), single pod weight (15.17gm), length of pods (11.58 cm), dry weight of pods (1039.33kg/ha), total pod yield (14.29t/ha) as yield related traits.

Brinjal

Anburani and Manivannan, (2002) assessed the effect of integrated nutrient management on growth in brinjal (*Solanum melongena* L.) cv. Annamalai. The results indicated that the treatment consisting FYM + Press mud 12.5 t ha⁻¹ each along with 100 per cent NPK + bio-fertilizers had the highest plant height (108.90 cm), number of primary branches (11.66) and number of leaves (94.05) whereas, FYM at 25 t ha⁻¹ along with 100 per cent NPK + bio-fertilizers (*Azospirillum* + PSB) recorded the highest stem girth (3.71 cm), number of secondary branches (15.58) in brinjal. However, Ullah *et al.*, (2008) observed the maximum number of fruits, maximum length of fruits and maximum fruit diameter and maximum fruit weight when plants were treated with 20% cowdung + 20% mustard oilcake + 20% poultry manure + 40% NPK fertilizers. Kumar and Gowda, (2010) conducted an experiment on effect of different organic manures and inorganic fertilizers on growth and yield of brinjal (*Solanum melongena* L.). Application of recommended 25 t/ha of FYM, N through vermicompost and green manure (50% each) + recommended NPK (125:100:50 kg/ha) recorded maximum plant height, number of leaves and total dry matter of plant. The number of branches was highest with the treatment of 150% recommended FYM only, earliness for first 50% flowering and first harvest was observed with 100% recommended FYM alone. Christo *et al.*, (2011) found higher fruit yield

(4,076kg/ha) and number of fruit per plant (79.0) with application of 7500 kg/ha include with pig slurry, but application of 5000kg/ha of poultry droppings gave the highest leaf yield. However, Vijay and Seethalakshmi, (2011) revealed that the application of Vermicompost made from *Parthenium* @ 5 t/ha + 50% RDF) gave maximum height of plant while, maximum fruit weight was recorded with (*Parthenium*Vermicompost2.5 t/ ha +FYM @ 6.25 t/ha). Suge *et al.*, (2011) conducted an experiment to evaluate the effect of combination between two levels of recommended dose of mineral fertilizers. The application of farmyard manure had significantly highest plant height of 58cm and 64.5cm and fresh weight of 370.67g and 407.67g as compared to other organic sources of manures and their control respectively in 2009 SRS.

During 2010 in LRS similar trend was observed with plant height of 57.3 cm and 62 cm for FYM compared to 39 cm and 42.33 cm for control respectively. However, Suchitra and Manivannan, (2012) found that the application of vermicompost @ 5t/ha and Humic Acid 0.2% had the number of fruits plant⁻¹ (30.11), length of fruit (14.30 cm) and girth of fruit (13.75 cm). Mujawar, (2012) carried out an experiment to assess the effect of organic and inorganic sources of nutrients on yield of brinjal. The results indicated that the treatment containing RDF+FYM recorded significantly higher fruit yield (5.24 t ha⁻¹) and it was on par with RDF and organics and chemical fertilizers applied each at 50 per cent level either alone or with liquid organics. Munshi, (2014) revealed that the application of 32 kg compost + 50% NPK gave the greater yield over all treatments that was statistically similar to 32 kg of compost (21.61 MT/ha, 21.24 MT/ha) respectively. The lowest yield (9.63 MT/ha) was obtained from the plots amended with 16 kg of compost. There was statistically similarity in the average weight

per fruit amongst the plots amended with 32 kg of compost, 32 kg of compost + 50% NPK and 100% NPK (47.78 g, 48.61 g, 47.80 g) respectively. Agrawal and Sharma, (2014) conducted a pot experiment to assess the impact of live earthworm + cattle dung (as feed), cow dung compost, vermicompost, chemical fertilizers and control (without fertilizer) on growth of brinjal (*Solanum melongena* L.). The results indicated that the application of live earthworm + cattle dung had maximum plant height, fruit weight, time taken in budding and flowering, consecutively and number of in treated plants followed by, vermicompost treated plants and it was minimum observed in control. Kashyap *et al.*, (2014) carried out an experiment to find the effect of different doses of organic manures and inorganic fertilizers on growth of brinjal var. Pant Rituraj. The result revealed that the treatment consists 25% RDF + 75% Neemcake produced maximum plant height, number of branches, number of leaves and maximum numbers of flowers were noted with 75% RDF + 25% Vermicompost, while, maximum fruit weight, fruit length, fruit diameter, number of fruits per plant observed under 25% RDF+75% Neemcake. Najar *et al.*, (2015) observed that different rates of vermicompost produced significant effect ($P < 0.05$) as compared to the control on growth parameters with maximum value recorded at 6 t/ha, followed by 4 t/ha and the least at 2 t/ha. Kumar, (2016) revealed that application of 50% RDF along with vermicompost @ 5 t/ha exhibited higher plant height and dry weight with in Brinjal. Zainub *et al.*, (2016) conducted an experiment to evaluate the response of brinjal during 2014. Achieved higher number of fruits plant⁻¹ (16.37), total yield (13.72 t ha⁻¹) with nitrogen at 130 kg ha⁻¹ by integrated sources of nutrients. The similar findings were also observed by Barman *et al.*, (2017) who reported that application of recommended dose of NPK 100:50:50 gave highest plant height (73.71 cm) followed by,

50% recommended dose of nitrogen through FYM + 50% nitrogen through poultry manure.

Potato

Jaggi *et al.*, (1995) studied the effect of FYM and phosphorus fertilizer on tuber yield of potato. The highest tuber yield was obtained with the application of 10 tonnes FYM with 60 kg P₂O₅ ha⁻¹. An experiment conducted by Patil *et al.*, (1997) to study the effect of vermicompost, FYM and inorganic fertilizers on growth, yield and uptake of nutrients in potato *cv.* Kufri Chandramukhi. The findings revealed that combination of VC @ 4 t ha⁻¹ + 50 per cent RDF given maximum yield (34 t ha⁻¹). While, Mrinal *et al.*, (1998) reported that integrated application of 75% of the recommended NPK (120:100:100 kg NPK ha⁻¹) + 2.5 t vermicompost produced highest marketable tuber yield. Similarly, Bhukta, (2000) revealed that the application of 10 t FYM along with 150:80:100 kg NPK ha⁻¹ produced maximum yield. The findings exhibited that absence of FYM, the application of 150 kg N, 100 kg K₂O and 40 kg P₂O₅ blended with cowdung slurry (2:1) proved equally better to that of 150:80:100 kg NPK ha⁻¹. Further, it had also been reported that 75:40:50 kg NPK ha⁻¹ can be saved, if it is applied along with cowdung @ 7.5 t ha⁻¹. Pervez *et al.*, (2000) studied the effect of organic manure and inorganic fertilizers particularly for increased doses of potash on the yield and quality of potato. Various doses of potassium (K₂O) i.e. 25, 50, 75, 100, 200 and 300 kg mixed with combined application of five tons rotted FYM ha⁻¹. Nitrogen and phosphorus were applied as a single constant dose *i.e.* 130 kg each ha⁻¹ at the time of sowing and at the time of earthing up, respectively. Potash application alone did not show any promising results, although increased levels of potassium increased the yield to some extent. Combined application of FYM and higher doses of potassium proved

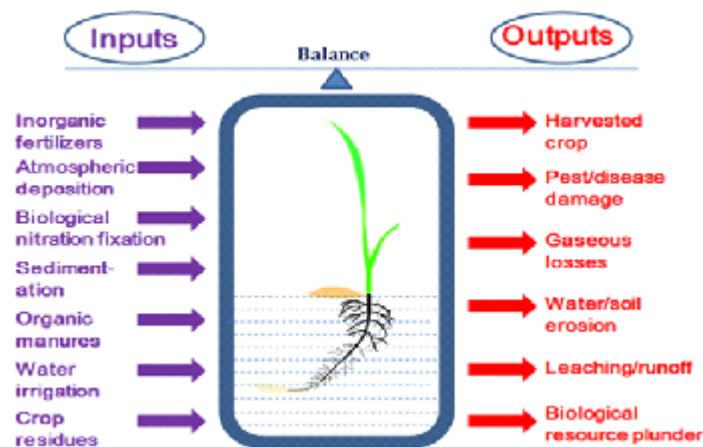
best to increase the yield of potato. Santlal, (2003) studied that the effect of nitrogen in the form of urea and bulky organic manure on production of potato. The plants treated with 100% Urea N + 250 q ha⁻¹ FYM attained maximum plant height, number of leaves per plant, number of tuber per plant, shoot weight (fresh and dry) per plant and tuber weight (fresh and dry) per plant and number of shoots per plant. Similar results were reported by Nag, (2006) who advocated that the growth parameters like plant height (cm), number of shoots plant⁻¹, number of compound leaves plant⁻¹, number of tubers plant⁻¹, fresh weight of shoots plant⁻¹, fresh weight of tubers plant⁻¹, dry weight of shoots plant⁻¹ and dry weight of tubers plant⁻¹ were influenced with the increase in per cent of RDF. The highest value of all the above parameters was recorded under the treatment consisting 125% RDF + organic manure (FYM) @ 20 t ha⁻¹. Sood, (2007) reported that combined use of organic and inorganic fertilizers in the ratio of 1:3 significantly increased plant growth parameters, tuber yield and nutrient uptake. The higher tuber yield under integrated use of organic and inorganic fertilizers was mainly due to higher proportion of large and medium size tubers. While, Solanke *et al.*, (2009) observed that the plants treated with 100% RDF + 5 t FYM ha⁻¹ + Biofertilizers had maximized plant height (54.9 cm plant⁻¹), number of functional leaves (40.8 plant⁻¹), fresh weight of tubers (285.6 g plant⁻¹), total dry matter (69.7 g plant⁻¹) and tuber yield. Maximum net returns (Rs. 35749 ha⁻¹) and benefit: cost ratio (1.74) was also observed in the same treatment. Choudhary *et al.*, (2010) observed that vermicompost doses @ 20 or 30 t ha⁻¹ as well as biofertilizers alone or in combination with vermicompost increased plant height. However, application of vermicompost @ 30 t ha⁻¹ along with co-inoculation of PSB and *Azotobacter* appeared to be the best treatment combination over other treatments to realize highest

productivity, profitability as well as soil fertility in potato under organic production in North-Western Himalayas. While, Sarkar *et al.*, (2011) assessed the positive effect of application of nutrients from organic and inorganic source and their combinations on plant height, dry matter production, number of shoots, number of tubers, tuber yield of potato and highest net return was obtained with 40 % organic + 60 % inorganic followed by, 50% organic + 50 % inorganic than other treatments. Similarly, Yadu (2011) concluded that the growth parameters like plant height, number of leaves plant⁻¹, fresh weight of shoots plant⁻¹ dry weight of shoots plant⁻¹, fresh weight of tubers plant⁻¹ and dry weight of tubers plant⁻¹ were influenced with the increase in the per cent of RDF.

Kumar (2012) conducted three years experiment to study the effect of integrated nutrient management on growth and economic yield of potato. The pooled data obtained from the study revealed that integrated application of 50 % of recommended NPK through inorganic and 50 % RDN through PM recorded significantly highest tuber yield (22.73 t/ha) followed by, 100 % recommended NPK through inorganic (22.20 t/ha) which were 228 % and 223 % respectively and its lower value observed in control. Integrated application of inorganic and organic fertilizers and seed treatment with *Azotobacter* + PSB biofertilizers improved tuber yield, nutrient uptake, and gave higher return as compared to other treatment combinations. Chandrakar *et al.*, (2013) revealed that the application of 75% N inorganic fertilizer + 25 % N organic (Poultry manure) + PSB + *Azotobacter* produced significantly highest growth parameters, yield attributes (number of stolons plant⁻¹, number of tubers plant⁻¹, fresh weight and dry weight of tubers, tuberization efficiency) and total tuber yield. Congera *et al.*, (2013) assessed the effect of water management weed and integrated nutrient

management on yield of potato. The findings revealed that the application of 50% RDF + 50% FYM + *Azotobacter* + *Phosphobacteria* recorded maximum total dry matter production (21.67%) Similarly, the maximum uptake of N (97.17 kg ha⁻¹), P (21.76 kg ha⁻¹) and K (159.63 kg ha⁻¹) was found with plants provided 50% RDF+50% FYM + *Azotobacter* + PSB. However, Baishya *et al.*, (2013) observed that the application of 75% recommended dose of fertilizers (RDF) through chemical fertilizers along with 25% recommended dose of nitrogen (RDN) through farm yard manure (FYM) and/or 100% RDF through chemical fertilizers recorded higher values of the yield parameters and produced higher tuber yield (26.0 and 25.6 t ha⁻¹) than other treatments. Sayed *et al.*, (2014) observed the effect of organic fertilization alone or with bio-fertilization could replace mineral fertilization in potato production with no adverse effect on quantity or quality of potato tubers. The highest plant height, haulm fresh weight, number of main stems, leaves content of phosphorus and potassium and total and marketable yields obtained from potato plants treated with 35.7 mt. ha⁻¹ of compost at 90 days after planting, compared to the control. The results indicated that organic production of potato using 23.8 mt.ha⁻¹ of compost could be alternative sources of nutrients to replace conventional production without significant reduction in yield and quality. Yadav and Shrivastava, (2015) studied that the effect of integrated nutrient management on production of seed tubers of potato (*Solanum tuberosum* L.) from true potato seed. Integrated use of synthetic fertilizers and organic manures showed the significant impact on growth and yield attributes of potato. Highest yield of tubers (12.4 t ha⁻¹) were recorded with application of 75% RDF through fertilizers and 25% RDN through FYM which was significantly superior over rest of treatments.

Fig.1 The nutrient budgets between inputs and outputs, and the principles of INM method (Jat *et al.*, 2015)



Singh *et al.*, (2017) reported that the bio-fertilizers have stimulatory effect on germination, sprouting behaviour and growth parameter of potato. The maximum germination and number of bud tuber⁻¹ with 5 in number was recorded with FYM @ 150g pot⁻¹ + Mustard cake @ 150g pot⁻¹ + tuber treatment with *T. viride* + foliar spray with bio-formulation of *T. viride*. It was also mentioned in the study that bio-fertilizers have stimulatory effect on vigour of plants. The maximum plant height was recorded with soil application of mustard cake + tuber treatment and foliar spray with *T. viride* with the value of 11.16 cm at 30 day age of plant. The effect of seed treatment and foliar spray with bio-fertilizer on tuber size and yield was recorded with the same treatment.

Other vegetable crops

Kale *et al.*, (1991) reported that quantity of fertilization could be reduced by 25 to 30 per cent in radish, tomato, carrot and brinjal with application of vermicompost. However, Desai (1992) stated that application of one tonne vermicompost per hectare in capsicum resulted in slightly low yields as compared to chemical treatment plot while, net profit was more in vermiculture treated plots due to less

cost of total inputs. Chattoo *et al.*, (1997) studied the effect of biofertilizers and nitrogen on growth, yield and quality in Knol khol cv. Early White Vienna. Among the biofertilizers, *Azospirillum* proved better than *Azotobacter* in terms of better growth and yield of Knol khol. Increase in carrot yields was observed even with application of vermicompost (Ravindrababu, 1999). Reddy (2000) examined the effect of integrated nutrient management with vermicompost and nitrogenous fertilizer in onion (*Allium cepa* L.) – Radish (*Raphanus sativus* L.) cropping system for sustainable crop production. The results indicated that in radish the residual nutrients due to application of 30 t vermicompost in onion resulted as significant increase in bulb yield (42.03 t ha⁻¹). Shalini *et al.*, (2002) assessed the combined effect of nitrogen with 50 and 75 % of the recommended dose (150 kg/ha) of nitrogen, organic manures (farmyard manure + vermicompost) with and without *Azospirillum* on yield of Knolkhol. The maximum plant height (16.42 cm), number of leaves (19.42 cm), dry matter production (35.41 g/plant) and maximum yield (37.21 t/ha) were recorded with 50 % of N was sourced through inorganic and another 50 % nitrogen through Vermicompost +

Azospirillum. Available soil nitrogen was significantly higher in plots receiving organic manures and *Azospirillum* biofertilizer than those in inorganically fertilized plots. Prasad and Gaurav, (2004) noticed that the plants treated with *Azospirillum* along with *Azotobacter* gave highest yield (14.11 t/ha) in sprouting broccoli cv. Aishwarya. The application of organics viz., FYM, chilli stalks and FYM + chilli stalks with inorganic fertilizers (RDF) significantly influenced growth, yield nutrient uptake and quality of chilli and the magnitude of combined effect of organic and inorganic was higher than inorganic alone (Kattimani, 2004). However, Padamwar and Dakore (2009) found the application of vermicompost (5 t/ha) and *Azotobacter* (10 kg/ha) to be most beneficial in increasing the yield and quality of cauliflower. Gupta *et al.*, (2010) studied the role of INM on growth, vegetable yield and quality of Knol khol with bacterial inoculants (*Azospirillum* and *Azotobacter*). The findings revealed that all levels of nitrogen with both bacterial inoculants significantly increased in growth, yield and quality parameters as compared to control. However, better results were obtained by the application of 75 % of chemical nitrogen along with both the inoculants thereby resulting a saving of 25 % chemical nitrogen application. The results also demonstrated that the application of *Azospirillum* along with 75 % chemical nitrogen proved better than *Azotobacter*. Sharma *et al.*, (2012) investigated the response of cucumber, knol khol, broccoli and radish to the use of integrated nutrient management practices. The varieties used for study were Summer Green of cucumber, G-40 of Knol Khol, Early Green in case of Broccoli and CR-45 of Radish. Cucumber recorded highest yield of 213.85 q/ha with Neem Cake at 5 t/ha. It was 17% superior to the recommended dose of chemical fertilizers. Yields were comparatively low with farm yard manure (FYM) vermicompost and

poultry manure. Knol khol gave maximum yield with full dose of NPK + seedling treatment with *Azotobacter* at the time of transplanting with superiority of 45% over sole application of chemical fertilizers. Yields were reported low with organic treatments but FYM with seedling treatment with *Azotobacter* yielded satisfactorily to the level of 253.3 q/ha. Broccoli responded well to INM treatment but yielded enough with FYM at 20 t/ha and poultry manure at 5 t/ha to justify its consideration of organic production. The results also demonstrated that vermicompost in combination with half dose of chemical fertilizers exhibited excellent in broccoli and radish. However, application of FYM and vermicompost alone were superior to the use of chemical fertilizers. A yield advantage of 12 and 4% was obtained over recommended dose of chemical fertilizers with their respective application. The investigations revealed that integrated use of nutrient source is superior in application to chemical fertilizers alone. Singh and Kumar, (2016) studied the effect of integrated nutrient management on growth, yield and nutrient uptake of clusterbean (*Cyamopsis tetragonoloba*). The results showed that application of 50, 75 and 100 % of recommended dose of fertilizer (20 kg N, 40 kg P₂O₅ /ha) gave 21.2, 45.7 and 50.8 % higher yield over the control respectively. Association between *Rhizobium* and phosphate solubilising bacteria was synergistic and inoculation of both fertilizers significantly improved the seed yield. Inoculation of *Rhizobium*, phosphate solubilising bacteria and *Rhizobium* + phosphate solubilising bacteria recorded 21.1, 14.1 and 24.7 % higher seed yield than the control respectively. However, the combination of both inoculants further failed to significantly increase the seed and straw yield of clusterbean further. Mohanta *et al.*, (2018) revealed that the application of 50% NPK + Vermicompost @2.5t/ha gave

maximum values for plant height (51.56 cm), plant spread N-S (61.63cm) and E-W (64.91cm), number of leaves per plant (22.27), leaf area (405.45cm²), leaf length (23.15cm), leaf width (18.18cm), days to 50% head initiation (50.67days) and days to first harvest (51.00). The same treatment was also found superior in terms of highest head girth (42.76cm), head diameter (14.16cm), terminal head weight (327.57g), head volume (595.67cc), gross yield (233.56q/ha), marketable yield (163.63q/ha), vitamin C (80.24mg/g), dry matter (11.77%), gross returns (Rs.700680.00/ha), net returns (Rs. 525510.00/ha) and benefit cost ratio (4.0).

In summary, the above findings clearly indicated that integrated sources of nutrients enhance the growth, yield, quality and soil fertility of vegetable crops as compared with control and recommended doses of inorganic fertilizers. This enhancement was appear due to proper and judicious uses of inorganic and organic sources of nutrients which resulted in adequate supply of NPK and essential micronutrients on larger quantity to plants. A judicial combination of organics, in-organics and bio-fertilizers has been proved to give the best results on growth, yields, quality and soil fertility in vegetable crops.

The above results showed that the pure chemical or pure organic treatments could not improve yield, quality of vegetables as well as fertility of soils. The integration of organics and biofertilizers along with chemicals has a positive effect on above parameters and only gives highest net returns but also increases soil fertility status in harvested vegetable crops.

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How to cite this article:

Mukesh Kumar, Veena Chaudhary, R.K. Naresh, O.P. Maurya and Pal, S.L. 2018. Does Integrated Sources of Nutrients Enhance Growth, Yield, Quality and Soil Fertility of Vegetable Crops: A Review. *Int.J.Curr.Microbiol.App.Sci*. 7(06): 125-155.
doi: <https://doi.org/10.20546/ijcmas.2018.706.017>