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INTEGRATED NUTRIENT MANAGEMENT (INM) APPROACH FOR BRINJAL (*SOLANUM MELONGENA* L.) AND OTHER SOLANACEOUS VEGETABLES -A REVIEW

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ABSTRACT

Integrated Nutrient Management (INM) implies the most efficient use and management of organic, inorganic and biological sources of major nutrients as well as micronutrients to attain higher levels of crop productivity and to maintain the fertility of the soil. Brinjal is one of the most popular and commercially important vegetable crops of India. Research works on INM system for brinjal crop is scanty. This paper has reviewed the research work carried out by various scientists in India and abroad. The review deals with the effect of different INM components on growth, yield, fruit quality, nutrient content and uptake, incidence of brinjal shoot and fruit borer (BSFB) as well as economics of brinjal and other Solanaceous vegetables.

Key words: Integrated nutrient management, INM, Brinjal, Solanaceous vegetables.

India is bestowed with vast diversity of flora, fauna, soil and agro climatic conditions. This makes it feasible to grow the largest number of vegetable crops in the world and is regarded as a horticultural paradise (Saravaiya and Patel, 2005). As many as 61 annual and 4 perennial vegetable crops belonging to different groups are commercially cultivated in India, occupying an area of 6.6 million hectare (ha) with a production of 101 million tonne (t) and stands at first position in the world (Attri *et al.*, 2004).

In India, brinjal (*Solanum melongena* L.) belonging to the order Polemoniales and family Solanaceae,is cultivated as one of the leading and the second major vegetable crops next to tomato, covering an area of 4.96 lakh ha with a total production of 78.81 lakh tonne, having productivity of 15.90 tonne ha^{-1} (Chadha, 2002). Major states growing brinjal are West Bengal, Orissa, Bihar and Gujarat.

The growth, yield and fruit quality of brinjal are largely dependent on number of interacting factors. Amongst them, INM system is the most crucial as well as basic factor and is found to exert a great influence not only on growth, yield and fruit quality of brinjal but also for obtaining sustained productivity. Plant requires essential 17 mineral elements for proper growth and completion of life cycle. Nickel (Ni) is the latest addition to the list of essential nutrients done in 1987 (Rattan and Goswami, 2002).

The continuous use of high level of chemical fertilizers leads to decrease the nutrient uptake efficiency of plants, resulting in either stagnation or decrease in yield and also causing environmental pollution (Singh and Kalloo, 2000).

In recent times the concept of Integrated Nutrient Management system has been receiving increasing attention worldwide obviously for reasons of economization of fertilizer usage, safeguarding and ensuring scientific management of soil health for optimum growth, yield and quality of crops in an integrated manner in a specific agro-ecological situations, through balanced use of organic and inorganic plant nutrients; so that one can harvest good yield without deteriorating soil health.

From nutrition point of view the role of organic manures is very meager; however, its value lies more in its action as a soil ameliorate, corrective for physical conditions and a parameter of biological activity to enhance soil productivity. Use of organic manure is inevitable for sustained agricultural production. The different components of INM possess great diversity in terms of physical and chemical properties and the nutrient release patterns (Pasricha *et al.*, 1996).

The relevant and important published work available on solanaceous vegetables has been reviewed and presented here under the following heads:

1 Role of organic manures
2 Effect of organic manures
3 Effect of inorganic fertilizers
4 Effect of combined application of organic manures and inorganic fertilizers
5 Response of micronutrients
6 Effect on incidence of brinjal shoot and fruit borer
7 Economics

1 ROLE OF ORGANIC MANURES

Soil health is one of the key factors which decides the yield. Organic manures are basic source of essential plant nutrients and applied in large quantities. They also contain other growth promoting agents like enzymes and hormones. Through the process of decomposition and humification they give humus, which helps to improve the physical, chemical and biological properties of the soil. The organic acids released during decomposition of organic manure controls certain fungal pathogens and nematode infestation (Senthilkumaran and Vadivel, 2002). Organic manures such as FYM, BC and PM are indispensable and are important components of INM system for maintaining soil fertility and yield stability (Pasricha *et al.*, 1996).

Application of organic manures to soil not only improves the physical properties but also increases the availability of nutrients as well as organic carbon content and cation exchange capacity (CEC). Moreover, it supplies plant nutrients including micronutrients and increases the yield of crop (Reddy and Reddy, 1999).

It is obvious that organic manures have both direct and indirect effects on crop productivity and environment. The uptake of humic substances or its decomposed products results in efficient metabolism and thereby better crop growth as well as yield (Mathur and Gaur, 1977).

The use of expensive chemical fertilizers as per requirements of crop is not much affordable to the average farmers. Therefore, the application of plant nutrients through organic source like compost, FYM and biofertilizer is advisable (Subbiah *et al.*, 1982).

2 EFFECT OF ORGANIC MANURES

2.1 Soil physical properties:

Organic manures help to improve and maintain the productivity. Badole and More (2000) reported the maximum organic carbon content (6.20 g kg^{-1}) with the treatment of FYM + Press mud cake + Glyricidia + Azotobacter + Phosphate solubilizing bacteria + Cow dung urine slurry. Similar results were also reported by Prasad and Singhania (1989).

Application of FYM has resulted in lowering pH, increased organic carbon content and CEC, apart from building up N, P and K (Sinha *et al.*, 1981).

A field experiment was conducted with tomato on sandy loam soil, by Renuka and Sankar (2001). They found that application of manures maintained the soil pH near to neutral, besides keeping lower levels of electrical conductivity and bulk density.

2.2 Growth:

Subba Rao and Sankar (1997) conducted an experiment and recorded that brinjal crop responded well to application of organic manures either alone or in combination besides improving the soil status. They further recorded that the effect of manures on dry matter production and other growth characters were significantly better than those of inorganic fertilizers. Additionally, manure treatments were equally effective compared to NPK treatments in the induction of early flowering in brinjal.

According to Renuka and Sankar (2001) vigorous growth of tomato with early flowering could be obtained with the application of FYM.

2.3 Yield and Quality:

Omori *et al.* (1972) reported that application of 10 tonne cattle manure per acre increased the yield of eggplant.Subba Rao and Sankar (1997) conducted an experiment and reported maximum brinjal fruit yield (12.31 t ha^{-1}) under the treatment of FYM + Vermicompost.An experiment was conducted on tomato by Renuka and Sankar (2001) and obtained higher yield (46.66 tonnes) with the application of FYM + biogas slurry, which was two and half times over the control (18.44 tonnes).

Research work conducted with tomato cv. ' PKM-1' by Prabakaran and Pitchai (2002), has revealed that the application of organic N sources increased TSS and ascorbic acid contents of tomato over control.

2.4 Nutrient Content and Uptake:

Patil and Patil (2000) recorded N, P and K contents in different cultivars of brinjal fruits which ranged from 2.04 to 3.26, 0.35 to 0.55 and 1.50 to 3.89 per cent, respectively.An increase in available N status by continuous addition of FYM was reported by Singh *et al.* (1980).

Muthuvel *et al.* (1982) stated that the higher available N content of soil with FYM addition could be due to the favourable microbial activity and an enhanced biomass addition to the soil, probably as a result of improved soil physical properties.

In general, the available N and P of soil after the crop harvest increased considerably as compared to initial level due to incorporation of FYM (Raju *et al.*, 1991). The available N was higher in treatment receiving entire dose of N as organic manures (Prameela, 1996).

Sankaran (1977) reported that application of FYM registered the highest available P content of the soil due to some organic acids produced during decomposition which caused the release of P from insoluble P compounds. Likewise, Duraisamy *et al.* (1986) also reported that application of 25 t FYM ha^{-1} increased the available P content.

Raju (1979) observed that application of FYM @ 25 t ha^{-1} significantly increased the available K status of the soil as compared to no manure at all stages of crop growth. Similarly, Singh *et al.* (1980) also observed that continuous application of FYM had resulted in a build up of available K in the soil.

The addition of farm wastes and organic manures increased the availability of N, P and K (More, 1994).

3 EFFECT OF INORGANIC FERTILIZERS

3.1 Growth:

Mertia and Chauhan (1970) from Udaipur reported that application of nitrogen was effective in increased plant height; number of leaves and brinjal fruits and that 89 kg N + 45 kg P_2O_5 + 45 kg K_2O was proved to be the most effective treatment. Gnanakumari and Satyanarayana (1971) concluded that fertilizer application hastened flower initiation markedly. Brinjal plants receiving 224 kg each of N, P and K flowered 27 days earlier than control plots.Nandekar and Sawarkar (1990) reported that NPK application significantly increased brinjal plant height and spread, the number of leaves as well as branches plant^{-1} and fruit length, diameter and weight as compared with the unfertilized control. The highest NPK rate (120 kg N + 75 kg P_2O_5 + 45 kg K_2O ha^{-1}) gave the best results. Philip (1995) conducted an experiment on brinjal cv. 'Surya' and recorded the maximum number of fruits per plant (12.9), percentage of fruit set (32.5) and mean weight of fruit (68.8 g) with the treatment receiving 75 kg N, 20 kg P_2O_5 and 25 kg K_2O ha^{-1}.

Patel (1984) working with brinjal cv. 'Surati Ravaiya' observed that application of 100 kg nitrogen per hectare, along with 37.5 kg each of P and K produced maximum height of plant (66.47 cm) under South Gujarat conditions.

Fertilizer trial was laid out by Vijaykumar *et al.* (1996) using 'Palur-1' cv. of brinjal. They reported that root length and dry matter production were significantly higher from the plants receiving the fertilizer level of 200: 100: 60 kg NPK ha^{-1}.

Working at Ludhiana (Punjab), Sat- Pal *et al.* (2002) suggested that the average number of fruits per plant and fruit weight was increased with an increase in N rate in *aubergine* cultivars 'BH-1' and 'BH-2'.

As per the results obtained by Khan and Suryanarayana (1978) working with capsicum, the maximum growth and dry matter production were recorded with the application of N at 120 kg ha^{-1} + P_2O_5 and K_2O each at 45 kg ha^{-1}.

Hossain and his co-workers (2001) conducting an experiment on chilli, found that application of 120 kg N , 30 kg P and 30 kg K ha^{-1} resulted in optimum plant height, number of branches per plant, flowering, fruit maturity and number of fruits.

3.2 Yield and Quality:

Patnaik and Farooqui (1964) observed that application of 90 kg nitrogen per hectare, along with 45 kg each of P and K increased the fruit set and yield of brinjal as compared with no application of fertilizers.

Choudhury (1976) opined that a good crop of brinjal required about 84 to 112 kg N, 84 to 112 kg P and 56 kg K per hectare. Likewise, Dhesi and Nandpuri (1965) also opined for a dose of 112 kg N, 56 kg P and 28 kg K ha^{-1} to obtain good yield of brinjal.

Gnanakumari and Satyanarayana (1971) reported that the highest yield of brinjal as well as vitamin C and dry matter contents were obtained from plots receiving N, P and K each at 280 kg ha^{-1}.

The highest yield of brinjal have been reported with 120 kg N + 80 kg each of P and K ha^{-1} by Bandopadhyay *et al.* (1972) in Bihar.

Sulikeri *et al.* (1977) conducting an experiment on eggplant cv. 'Malapur', recorded the highest yield with NPK at 80: 60: 40 kg ha^{-1}.

Mangual Crespo (1981) from a fertilizer yield equation stated that brinjal cv. 'Rosita' showed maximum yield (38 to 40,000 kg marketable fruits per hectare) with 398 kg N, 200 kg P and 253 kg k ha^{-1}. Reddy *et al.* (1988) obtained the highest mean fruit yield in brinjal (17.57 t ha^{-1}) with 187: 150: 75 kg NPK ha^{-1}.

Nandekar and Sawarkar (1990) carried out a study and recorded that the highest NPK rate (120: 75: 45 kg ha^{-1}) gave the highest fruit yield of brinjal (303.9 q ha^{-1}). An investigation was undertaken on 'Pragati' variety of brinjal by Deshmukh *et al.* (1996) and recorded the highest yield of brinjal (31.4 q ha^{-1}) with 100 kg N ha^{-1}.

Singh and Syamal (1995) observed that application of 100 kg N ha^{-1} produced the maximum number of brinjal fruits and yield; while fruits weight, total soluble solids and ascorbic acid contents were highest at 150 kg N ha^{-1}.

Murugan (2001) observed the highest ascorbic acid contents of green (100.4 mg 100 g^{-1}) and ripe (85.4 mg 100 g^{-1}) fruits of *C. annum* cv. 'CO.3 'with 120 kg N and 60 kg P ha^{-1}.

Khan and Suryanarayana (1978) recorded the highest yield (1440 kg ha^{-1}) of chilli cv. 'N P 46 A' with N at 120 kg ha^{-1} + P_2O_5 and K_2O each at 45 kg ha^{-1}.

3.3 Nutrient Content and Uptake:

Nikolaeva (1975) stated that the proportion of N, P and K in the soil had an appreciable affect on the total nutrient removal from the soil and on nutrient utilization by plants.Lakshmi *et al.* (2000) reported that N and K uptake showed a positive direct effect on yield at the genotypic level; while N, P and K at the phenotypic level registered a negative direct effect on yield.

Kadam and Sahane (2002) observed that NPK contents of tomoto fruit as well as plant and uptake were higher with the application of 100 per cent recommended NPK rate than with 75 per cent recommended NPK rate.

4 EFFECT OF COMBINED APPLICATION OF ORGANIC MANURES AND INORGANIC FERTILIZERS

4.1 General:

Santhy *et al.* (2002) concluded that organic carbon was recorded higher under the treatment of 100 per cent NPK (90: 45: 17.5 kg ha^{-1}) + FYM at the rate of 10 t ha^{-1}.Prasad and Singhania (1989) reported that combination of inorganic fertilizers with organic manures is better than the fertilizer alone in respect of some soil chemical characteristics.In several studies, combined application of organic manures and chemical fertilizers generally produced higher crop yields than when each is applied singly (Pasricha *et al.,* 1996).

Shelke *et al.* (2001) recorded highest organic carbon (0.62 %) under the treatment combination of 40 % N through urea + 60 % N through PM at Rahuri with brinjal cv. 'Krishna Hybrid'.

Zhang *et al.* (1988) reported that combined use of NPK fertilizers with organic manure, improved the supply of nutrients in a balanced manner and resulted in better growth, higher yield and better fruit quality of tomato plants.

Better nutrient management may be achieved by the involvement of organic sources, biofertilizers, chemical fertilizers and micronutrients (Singh and Kalloo, 2000).

4.2 Growth :

An investigation was conducted by Nanthakumar and Veeraragavathatham (1999) and the results clearly indicated that a combined nutrition of organic manure through 12.5 t ha^{-1} of FYM and 75 per cent of the recommended dose of inorganic N, P and K (75 kg N, 37.5 kg P and 30 kg K ha^{-1}) favourably increased the growth parameters.

Jose *et al.* (1988) recorded the greater plant height (75.15 cm), number of fruits plant^{-1} (13.07) and weight of fruits (1224.95 g plant^{-1}) from the brinjal plants receiving 50 kg N as urea and 50 kg N as PM.

Shelke *et al.* (1999) conducted a trial and the results obtained through this investigation indicated that the plant height, number of branches plant^{-1} and other growth parameters were significantly increased due to the application of N through organic and inorganic combinations.

Investigation was conducted by Som and his co-workers (1992). Maximum benefits in relation to different growth characters and yield were recorded at the highest level of oilcakes when applied with NPK fertilizers (80: 60: 60 kg ha^{-1}).

Chinnaswami (1967) reported that mixture of organic manures and inorganic fertilizers gave better results than organic manure alone.

Doikova (1978) reported that application of FYM + NPK increased dry matter production in brinjal; while, FYM alone proved less effective.

Kumaran *et al.* (1998) showed that tomato plant height and branches plant^{-1}, mean fruit weight and number of fruits per plant were best with organic + inorganic fertilizers.

Patil *et al.*(2004) working with tomato crop recorded maximum height of plant, number of primary branches and number of leaves with the treatment of 50 % RDF + 50 % FYM. Devi *et al.* (2002a) recorded the tallest plants, maximum fruit length, fruit girth, fruit weight and number of fruits plant^{-1} with 50 % N + 25 % poultry manure + biofertilizers, with *aubergine* cv. 'Jhuri Local' under West Bengal conditions.Mallangouda *et al.* (1995) from their study reported that application of the recommended dose of NPK + FYM improved the growth parameters of *C. annum* cv. 'Byadgi' at Main Research Station, Dharwad, India.

Hangarge *et al.* (2001) revealed that the application of vermicompost in combination with chemical fertilizers significantly increased growth attributes of chilli compared to organic manure and chemical fertilizers alone.Anburani *et al.* (2003) observed that the application of 25 t FYM ha^{-1} + 100 : 50 : 50 kg NPK ha^{-1} + bio fertilizers resulted in the maximum number of fruits (26.64 plant^{-1}), fruit length (10.77 cm), fruit girth (10.03 cm), fruit weight (54.11 g) and fruit yield of brinjal (1.43 kg plant^{-1}).Godse (1996)) recorded that the fresh weight of brinjal plant varied from 153 to 433 g under different treatments of organic manures and fertilizers under South Gujarat conditions.

4.3 Yield and Quality:

Sulikeri *et al*. (1977) conducted an experiment on eggplant cv. 'Malapur', planted at 75 x 45 cm or 75 x 75 cm along with a basal dressing of FYM at 10 t ha^{-1}; while, NPK was applied at 3 different levels. The highest yields were obtained at the closer spacing, with NPK at 80: 60: 40 kg ha^{-1}.

The brinjal fruit yields were highest (59.65 t ha^{-1}) in plots receiving FYM at 12.5 t ha^{-1} + NPK at half the standard rate. The highest FYM and NPK rates gave 53 t ha^{-1}; while, the control plants yielded 29.7 t ha^{-1} according to Subbiah *et al.* (1983).

Doikova (1979) obtained highest yield of eggplant cv. 'Trakiets' with 20 tonne FYM + 240 kg N, 120 kg P and 240 kg K_2O ha^{-1}; while, FYM alone proved less effective in brinjal. An investigation on the effect of INM was conducted by Nanthakumar and Veeraragavathatham (1999, 2000 & 2001) on yield of brinjal, variety 'Palur -1' during three seasons *viz., kharif, rabi* and summer. The results clearly indicated that a combined application of organic manure through 12.5 t ha^{-1} of FYM and 75 per cent of the recommended dose of inorganic N, P and K (75 kg N, 37.5 kg P and 30 kg K ha^{-1}) registered the highest yield of 36 t ha^{-1}. Further, they also reported that the keeping quality of brinjal was also favourably influenced with the same treatment.

Gattani *et al.* (1976) reported that if N fertilizer is used in combination with P and K plus FYM, higher yields can be obtained without causing any deterioration of soil physical properties.Som *et al.* (1992) recorded the highest yield (22.56 t ha^{-1}) of brinjal cv. 'Garia' when neemcake was applied @ 50 q ha^{-1} along with NPK fertilizers (80 : 60 : 60 kg ha^{-1}). In a study carried out by Patil *et al.* (1998) at Dharwad with tomato cv. 'Megha' recorded the highest yield (18.66 t ha^{-1}) with the recommended rate of inorganic fertilizer (NPK at 100 : 75 : 100 kg ha^{-1}) + vermicompost at 2 t ha^{-1}.

Chinnaswami and Mariakulandai (1966) in a trial with organic and inorganic manures on tomato cv. 'CO.1' found that combined application of FYM and inorganic mixture increased the ascorbic acid content and protein content as compared with groundnut cake and inorganic fertilizer alone. They also reported that keeping quality and storage life was better in combined application of FYM and inorganic mixture.

A trial was conducted at Ilfov in Romania between 1989 and 1993 by Lacatus *et al.* (1994). They concluded that the best quality processing tomatoes were obtained with N, P and K at 300: 150: 75 kg plus 20 t FYM ha^{-1}.

The results of Kumaran *et al.* (1998) showed that a combination of organic and inorganic fertilizers gave the best results in terms of yield. The quality parameters such as TSS and ascorbic acid contents were comparatively higher in organically grown tomato plants. Likewise, Harikrishna *et al.* (2002 a) 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 and his co-workers (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.

Sharu and Meerabai (2001) carried out an experiment at Vellayani (Kerala).The highest fruit yield (9.66 t ha^{-1}) was obtained with 50 % poultry manure + 50 % inorganic N.Working with chilli cv. 'Byadgi' under Vertisols of Dharwad (Karnataka), Patil and Biradar (2001) recorded the highest fruit yield (19.12 q ha^{-1}) with the application of 200 % RDF + FYM (10 tonne ha^{-1}) + VC (2.5 t ha^{-1}). Petkov (1964) recorded the best quality of capsicum from combined application of organic manures and fertilizers.

A field experiment was conducted by Shashidhara *et al.* (1998) and they reported that organic sources have no significant influence on dry pod yield. Application of 100 % RDF (150 : 75 : 75 kg ha^{-1} N:P_2O_5:K_2O) together with FYM 5 t ha^{-1} increased dry pod yield (mean 639 kg ha^{-1}) significantly over 50 % RDF (558 kg ha^{-1}).

Mallangouda *et al.* (1995) reported that application of the recommended dose of NPK + FYM improved the yield and yield components of capsicum. The highest fruit yield (2099.8 kg ha^{-1} FW and 577.8 kg ha^{-1} DW) was recorded with the same combination.

Selvi *et al.* (2004) reported that combination of NPK (100 : 50 : 50 kg ha^{-1}) + organic manures (CCP 25 t ha^{-1}) + micronutrients ($ZnSO_4$ @ 25 kg ha^{-1} and $FeSO_4$ @ 50 kg ha^{-1}) recorded the highest brinjal yield (21.90 t ha^{-1}) compared with NPK application alone (16.28 t ha^{-1}).

Subbiah (1994) registered the highest total dry yield (5.65 t ha^{-1}) of chilli cv.'CO.1' with the combination of 100 % recommended dose of NPK + biofertilizer.

4.4 Nutrient Content and Uptake:

Hegde (1997) reported that solanaceous vegetables (tomato, eggplant, chilli and bell pepper) generally take up large amounts of nutrients. The quantity depends on the quantity of fruit and DM they produce, which in turn is influenced by a number of genetic and environmental variables. The tomato plants, to produce 1 t fresh fruit, on an average need to absorb, 2.5-3 kg N, 0.2-0.3 kg P and 3-3.5 kg K; eggplant need 3-3.5 kg N, 0.2-0.3 kg P and 2.5-3 kg K; while chilli and bell pepper need 3-3.5 kg N, 0.8 -1 kg P and 5-6 kg K. Fruit and fruiting parts in this group of vegetables contain 45-60 % of total N, 50-60 % of the total P and 55-70 % of total K absorbed by the plants.

A study of integrated nutrient management on availability of nutrients uptake and yield of tomato cv. 'Megha' from Dharwad, Karnataka, India, Harikrishna *et al.* (2002a) revealed that the application of 25 t FYM ha^{-1} + 75 % N + 100 % P + 100 % K resulted in the highest available N (299.9 kg ha^{-1}), P_2O_5 (44.2 kg ha^{-1}) and K_2O (321.9 kg ha^{-1}) and the highest uptake of N, P and K at harvest.

Godse (1996) conducted an experiment to study the effect of organic manures and fertilizers on pest complex of brinjal and rationalization of spray schedule under South Gujarat conditions. In brinjal fruit, he recorded 2.13 to 3.26 % N, 0.24 to 0.30 % P and 2.73 to 4.03 % K contents.

Mallangouda *et al.* (1995) at Dharwad (Karnataka) carried out an experiment on growth, yield and yield components of chilli cv. 'Bellary Red'. The highest uptake of N (62.68 kg ha^{-1}), P (8.36 kg ha^{-1}) and K (37.28 kg ha^{-1}) was observed in the 50% recommended dose of NPK + FYM treatment.

Ismail *et al.* (1997) working with chilli cv.'Pusa Jwala' recorded maximum uptake of N (22.34 kg ha^{-1}) when FYM and urea was combined *i.e.* 75 kg N ha^{-1} through FYM + 75 kg N ha^{-1} through urea. Phosphours (2.84 kg ha^{-1}) and potassium (8.79 kg ha^{-1}) uptake had also similar pattern as that of N.

Subbiah (1994) noticed that 100 % RDF of NPK + biofertilizers inoculation to chilli had recorded the highest N (168.70 kg ha^{-1}), P (34.73 kg ha^{-1}) and K (255.20 kg ha^{-1}) uptake.Selvi *et al.* (2004) under Coimbatore conditions, noticed that N, P and K uptake by brinjal cv. 'CVK' ranged from 80.9 to 172.2, 7.6 to 14.4 and 81.0 to 134.0 kg ha^{-1}, respectively whereas, N, P and K contents of fruits were recorded from 2.60 to 3.16, 0.36 to 0.45 and 3.00 to 3.84 per cent, respectively in combination with NPK, organic manures and micronutrients.

A study was undertaken to compare the efficacy of organic versus inorganic forms of nitrogen on growth and yield of brinjal cv. 'MDU-1' by Jose *et al.* (1988). The results indicated that application of half N (50 kg) as PM and half N (50 kg) as urea increased the dry matter (39.4 to 95 g $plant^{-1}$) and uptake of N (27.9 to 135.5 kg ha^{-1}), P_2O_5 (8.5 to 34.0 kg ha^{-1}) and K_2O (50.9 to 126.3 kg ha^{-1}).

5 RESPONSE OF MICRONUTRIENTS

Now-a-days, vegetable crops are responding to micronutrients and their use in vegetable growing would be of great significance. The micronutrients namely; zinc, boron, manganese, iron, molybdenum and copper play an important role in vegetable production. Micronutrients play a catalytic role in nutrient absorption and balancing other nutrients (Singh and Kalloo, 2000). Review related to Zn and Fe only has been compiled.

5.1 Zinc (Zn):

Zinc (Zn) was discovered as an essential plant nutrient by A.L. Sommer and C.P. Lipman in the year of 1926 (Rattan and Goswami, 2002).

Zinc atomic No. 30 and atomic weight 65.37 is one of the seven essential plant micronutrients. The role of zinc application in improving crop productivity is as important as that of major nutrients in present day agriculture. Zinc is now being regarded as the third most important limiting nutrient element in crop production after N and P. Increasing cropping intensity and accompanying changes in the soil and fertilizer management practices alter the 'Zn' status of soil and its availability.

5.1.1 Role of Zinc in plants:

Zinc is essential for several enzyme systems which regulate various metabolic activities in plants. It is involved in auxin production, which is endogenous growth regulating substance. Zinc is also vital for the oxidation processes in plant cells and helps in the transformation of carbohydrates and regulates sugar in plants. Under 'Zn' deficient conditions, flowering and fruit development are reduced and maturity is delayed. The end result is lower yield, poor quality and sub-optimal nutrient use efficiency (Gupta, 1995).

5.1.2 Rate of 'Zn' application:

An application of 25 kg of $ZnSO_4$ ha^{-1} is recommended every three years for any field crop grown in Zinc-deficient soil (Tandon, 1989).

5.1.3 Crop uptake and removal of Zinc:

Zinc is absorbed as Zn^{2+} from soil solution through roots. The amount of 'Zn' absorbed depends on soil, crop, variety, yield and climatic conditions along with management practices. The uptake of 'Zn' at economic yield of most of the crops varies between 80 and 980 g ha^{-1} (Gupta, 1995).

5.1.4 Effect of Zinc on Growth:

Mallik and Muthukrishnan (1980) found that soil application of 'Zn' was highly significant in increasing the tomato plant height by 20 per cent.

Ranganathan *et al.* (1995) revealed that applying additional trace elements to the soil increased growth and flowering compared with NPK alone.

Reddy *et al.* (1986) observed that plant height, fruit number, fruit length and fruit diameter of brinjal were increased significantly with 50 and

75 kg $ZnSO_4$ ha^{-1} in combination with NPK over NPK alone.

5.1.5 Effect on Yield and Quality:

Dhakshinamoorthy (1977) reported that brinjal responds to application of 'Zn' in deficient soil and observed 17.5 per cent increase in brinjal yield.

Bid *et al.* (1993) reported that Zinc sulphate at 10 kg ha^{-1} reduced 'Zn' deficiency symptoms in eggplant and significantly increased yield. Similarly, Reddy *et al.* (1986) recorded the maximum fruit yield (15.17 t ha^{-1}) of brinjal cv. 'Pusa Purple Long' under the treatment of NPK + 50 kg $ZnSO_4$ ha^{-1}. Mallik and Muthukrishnan (1980) suggested that tomato yield ha^{-1} tended to be increased by soil application of Zn.

Dhakshinamoorthy and Krishnamoorthy (1989) concluded that application of 'Zn' depressed the ascorbic acid content of fruits; whereas, it increased TSS. Fruit yield (17.5 per cent) was significantly increased by the application of zinc. Application of 'Zn' up to 40 kg ha^{-1} is recommended for optimum yield. Further, the effect of 'Zn' on yield and quality of brinjal cv. 'Annamalai' was studied in a silty clay loam soil, deficient in 'Zn' by Ravichandran *et al.* (1995). Research results indicated that the highest yield (27.1 t ha^{-1}), number of fruits plant^{-1} (20) and the highest ascorbic acid content (16.48 mg 100 g^{-1}) were obtained by single soil application of $ZnSO_4$ (25 kg ha^{-1}).

Reddy *et al.* (1985) assessed the effects of various micronutrients on tomato cv. 'Pusa Ruby'. They recorded the highest yield of 202.1 q ha^{-1} under NPK + 75 kg Zn ha^{-1}. Similarly, Pillai (1967) also found that soil application of Zn at the rate of 11.2 kg ha^{-1} was effective in increasing the yield of chilli. Iyengar and Edward Raja (1988) found that in eggplant (Brinjal), soil application of $ZnSO_4$ @ 5 kg ha^{-1} showed significant response in increasing the yield. Selvi and his co-workers (2004) recorded maximum yield (21.90 t ha^{-1}) was obtained under the combined application of NPK (100 : 50 : 50 kg ha^{-1}) + $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 50 kg ha^{-1} + organic product over NPK (100 : 50 : 50 kg ha^{-1}) application alone (16.28 t ha^{-1}) and control (12.90 t ha^{-1}) in brinjal cv. 'CVK (Coimbatore Vari Kathiri)'.

5.1.6 Effect on Nutrient Content and Uptake:

Dhakshinamoorthy and Krishnamoorthy (1989) recorded that available N fell from a maximum 209.2 kg ha^{-1} initially to 173.7 kg ha^{-1} at post harvest. The available P was highest (14 kg ha^{-1}) with Zn at 10 kg. The application of Zn at 20 and 10 kg ha^{-1} increased the available K to 320 and 380 kg, respectively. Duraisamy *et al.* (1986) reported that application of 'Zn' increased the available N content and decreased the available P content.

Working with brinjal cv. 'CVK' in Coimbatore, Selvi *et al.* (2004) recorded that the 'Zn' uptake ranged from 278 to 493 g ha^{-1}. They further noticed that the content of 'Zn' in brinjal fruit ranged from 112.8 to 154.4 ppm. Patil and Patil (2000) conducted an experiment to study the micronutrient content of brinjal fruit and recorded 'Zn' content from 9.33 to 23.67 mg kg^{-1} in fruits of eighteen cultivars of brinjal.

5.2 Iron (Fe):

Iron (Fe) was discovered as an essential plant nutrient by E Gris in 1843 (Tandon, 1995).

5.2.1 Role of Iron in plants:

Iron is a constituent of a large number of metabolically active compounds like cytochromes; heme and nonheme enzymes and other functional metalloproteins such as ferrodoxin and heamoglobin. The best known role of iron is its catalytic function in biological oxidation and reduction and other metabolic processes in plants like oxidative photophosphorylation during cell respiration. Iron is involved in the formation of chlorophyll even though it is not its constituent. Iron is also known to be involved in carbohydrate metabolism. It may also be associated with organic acid metabolism (citric acid, mallic acid and ascorbic acid). It is related to vitamins, biological nitrogen fixation and Cu, Zn, Mn and Mg metabolism (Malewar and Ismail, 1995).

5.2.2 Rate of 'Fe' application:

An application of 50 kg of $FeSO_4$ (ferrous sulphate) ha^{-1} is recommended every three years for any field crop grown on iron deficient soil (Tandon, 1989).

5.2.3 Crop uptake and removal of Iron:

Iron uptake by crops is highest among micronutrients but the amounts absorbed are poorly translocated from the roots to the upper plant part (Shinde and Daftardar, 1987). Uptake of iron is characterized by factors like selectivity, accumulation and genotype (Ramani, 1987). It takes place either passively or actively. There is a wide variation in uptake and removal of iron by crops. Disparity between soil 'Fe' supply and crop uptake suggests the involvement of several factors: such as particle size, oxidation of bivalent ions in soils, interaction between micronutrients, soil microbial oxidation-reduction, formation of organic complexes in soils, variation in Fe requirement of crop species and influence of climatic factors on availability of iron (Malewar and Ismail, 1995).

The total uptake of Iron by 1 tonne yield of brinjal ha^{-1} was recorded as 320 g by Dangarwala (1983).

5.2.4 Effect on Yield and Quality:

Kumbhar and Deshmukh (1993) found that soil application of 80 kg $FeSO_4$ ha^{-1} was significantly superior in respect of tomato fruit yield; it gave 14.03 per cent higher yield than control.

5.2.5 Effect on Nutrient Content and Uptake:

Selvi *et al.* (2004) recorded that the 'Fe' uptake ranged from 2.16 to 3.49 kg ha^{-1} as well as 'Fe' content in brinjal fruit ranged from 313 to 401 ppm. They concluded that brinjal responded well to the application of micronutrient alone and in combination with NPK and other organic sources.

6 EFFECT ON INCIDENCE OF BRINJAL SHOOT AND FRUIT BORER (BSFB)

The brinjal crop is attacked by a number of insect pests; among them, brinjal shoot and fruit borer (*Leucinodes orbonalis* Gn.) is the most destructive key pest.

Tandon (1973) concluded that the increased trend of pest incidence with crop nutrition was evident and the most common reasons for the susceptibility were luxuriant growth, high nitrogen content, greater succulency, profuse tillering, more foliage and heavy shade.

Under South Gujarat conditions upto 5.76 per cent shoots and 47.67 per cent fruits were observed to be infested by shoot and fruit borer in brinjal (Patel, 1992).

Sinha *et al.* (1976) conducted an experiment brinjal and noticed that the percentage of shoot and fruit borer infestation was significantly increased with increasing level of nitrogen. Likewise, Mehto and Lall (1981) in their study on brinjal shoot and fruit borer at Bihar found maximum infestation of fruits (33.78 %) and maximum shoot infestation (33.00 %) under the treatment of higher level of nitrogen (60 kg ha^{-1}). Similarly, Chaudhrai and Kashyap (1987) also found that an increase in doses of nitrogen and phosphorus resulted in heavy infestation. Patnaik *et al.* (1998) recorded that application of 125:80:100 NPK kg ha^{-1} resulted in higher shoot and fruit borer infestation (35.4 to 44.4 %); while, plots receiving no fertilizers showed minimum infestation (26.1 to 27.6 %).

Godse and Patel (2003) observed lowest incidence of brinjal shoot and fruit borer (6.08 %) with the treatment of neem cake; while, it was found more (20.22 %) with the treatment of 200: 37.5: 37.5 NPK kg ha^{-1}.

7 ECONOMICS

The tomato crop supplied with a combination of organic and inorganic fertilizers was found to be economical and registered a benefit: cost ratio of 2.19: 1 (Poopathi, 1994).

Selvi and Thiageshwari (2002) studied the effect of INM on yield of brinjal reported that the integrated nutrient application yielded higher net return over the application of NPK alone. Similarly, effect of INM on yield and economics of brinjal cv. 'Jhuri Local' was studied in Nadia, West Bengal by Devi *et al.* (2002b). Treatment with 50 % N + 25 % poultry manure recorded the highest benefit: cost ratio (7.72: 1).

A field experiment on yield and economic analysis as influenced by integrated nutrient management was conducted by Harikrishna *et al.* (2002 b) at Dharwad, Karnataka, India on tomato cv. 'Megha (L-15)'. They recorded the highest net income of Rs. 78565 ha^{-1} and benefit: cost ratio of 2.72: 1 with the application of FYM 25 t ha^{-1} + 75 % RDN. They also recorded the lowest net income of Rs. 37684 ha^{-1} and benefit: cost ratio of 1.67: 1 with the treatment of FYM alone.

A field trial carried out in 1993-94 at Dharwad by Patil *et al.* (1998) to study the response of new tomato genotype 'Megha' to integrated nutrient management realized the highest benefit : cost ratio (3.47:1) with the recommended rate of inorganic fertilizer (NPK at 100 : 75 : 100 kg ha^{-1}) + Vermicompost at 2 t ha^{-1}.

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