Environment and Ecology 36 (4A) : 1231—1238, October—December 2018
Website: environmentandecology.com ISSN 0970-0420

Review on Integrated Nutrient Management and Organic Amendments on Growth, Yield, Quality and Economics of Chilli

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Received 8 June 2018; Accepted 14 July 2018; Published on 10 August 2018

Abstract The study reviews the use of chemical fertilizer, organic manures like FYM, poultry manure, vermicompost, neem cake, crop residues and organic amendments like panchagavya, jeevamrut, cow urine on chilli crop in an integrated approach at different localities of India. The study also focuses on growth parameters like plant height, stem girth, number of primary and secondary branches per plant, leaf area index and yield parameters like number of flowers/plant, number of fruits/plant, number of flower clusters/plant, fresh weight and dry weight of fruit, plants with the INM approach. The quality attributes like capsaicin content, vitamin C and keeping quality were also influenced by organic manures and amendments. The comparison of economics (benefit : cost ratio) of chilli crop with the different nutrient management practices and organic amendment were also given attention.

Keywords INM, Organic manures, Organic amendments, Growth, Quality.

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Introduction

Chilli or pepper (*Capsicum annuum* L.) belongs to family Solanaceae. It is one of the most valuable crops of India and is widely cultivated throughout the warm, temperate tropical and subtropical countries. Chilli was originated in tropical America. The genus capsicum is a source of products that are utilized around the globe. The chillies are unique, being used both as vegetable and spice . The crop is grown largely for its fruits all over the India. It is used in India as a principle ingredient of various curries and chutneys. It is also used as vegetable, spice, condiment, sauces and pickles. Dry chillies are used for curry powder. They provide pungency, flavoring and color to foods. They also provide essential vitamins, minerals and nutrients. Chilli extracts are used in pharmaceuticals, cosmetic products, paints and chilli sprays. In addition to their use as food, condiment, medicine and chillies are also used for their ornamental beauty.

In India, the increasing population on a near stabilized agricultural land places a heavy burden on the soil resource particularly its nutrient supplying power. Intensive agriculture involving the use of chemical fertilizers in large amount has, no doubt, resulted in manifold increase in the productivity of farm commodities but, the adverse effects of these chemicals are clearly visible on soil structure, micro flora, quality of water, food and fodder. Integrated nutrient management envisages the comprehensive management approach to improve the soil health, eco-system of the region and the quality of produce. A live healthy soil with proper cropping pattern and integrated nutri-

ent managemt can sustain optimum productivity over the years. However, a living soil can be maintained by continuous incorporation of crop and weed biomass, use of animal dung, urine-based manures viz., FYM, compost along with organic amendments such as jeevamrut, panchagavya and Gomuthra besides achieving higher growth, yield and quality of crops. In this context, the literature pertaining to the integrated nutrient management or nutrition in chilli is reviewed below.

Integrated nutrient management practices on the performance of chilli

Nutrient management

N at 120 kg ha^{-1} + P_2O_5 and K_2O each at 45 kg ha^{-1} recorded the highest yield (1440 kg ha^{-1}) of chilli cv NP 46 A (Khan and Suryanarayana 1978). The seedlings of the capsicum cv Jwala were raised on soil fertilized with ammonium sulfate, urea, green manure (unspecified) poultry manure or FYM and it was concluded that, vitamins B_1, C and E was highest in seedlings receiving ammonium sulfate (De and Laloraya 1980). The capsaicin content of the ripe pods was significantly influenced by the various NPK rates, being reduced in particular by the omission of K. The highest capsaicin content (17.2%) was with 80:0:35 NPK. Plants with no additional NPK contained 13.4% capsaicin but the lowest content (10.4%) was with the 0:35:0 and 120:0:0 NPK treatments (Subbaih et al. 1980). Application of N in four splits at 30 days intervals has been recommended by Singh and Srivastava (1988) to achieve maximum yields and profits in chilli production. The combination of fertilizers containing N at 125 or 175 kg ha^{-1} with FYM significantly increased the yield compared with the organic or inorganic fertilizers applied alone. The number and weight of unmarketable fruits recorded after 10 days of storage increased with increasing rates of FYM and fertilizers (Meena Nair and Peter 1990). The highest yield of chilli when both N and K were applied in four splits at planting, 30, 60 and 90 DAT (Subhani et al. 1990). Hosmani (1993) also reported higher yield of chilli with integrated use of chemical and organic fertilizers than with the use of either of these separately. Subbiah (1994) registered the highest total dry yield (5.65 t ha^{-1}) of chilli cv CO.1 with then combination of 100% recommended dose of NPK + biofertilizers. A significant increase in fruit length, number of fruits per plant and fruit yield of chilli with increase in nitrogen levels.The highest was being at 150 kg N ha^{-1} (Sharma and Peshin 1996). Similarly, significant improvements in yield and yield attributes of chilli due to application of phosphorus (90 kg ha^{-1}) reported by many earlier scientists (Narasappa et al. 1985). The highest fruit length (13.11 cm) with the application of 150:75:75 kg N, P_2O_5 and K_2O ha^{-1} (Balaraja 1999). A significantly higher fruit yield (5434.00 kg ha^{-1}) with the application of 180:40:40 kg N, P_2O_5 and K_2O per ha was recorded earlier. Shashidhara (2000) reported that application of 100% RDF (100:50:50 kg N:P_2O_5 : K_2O ha^{-1}) recorded maximum fruit yield of chilli (629.60 kg ha^{-1}) as compared to 50% RDF and control (509.33 kg ha^{-1}).

Singh et al. (1999) reported that application of higher dose of K_2O resulted in a significant improvement in fruit yield of chilli. Further, they also reported that the combined application of N and K (120:105 kg ha^{-1}) resulted in significantly higher fruit length, fruit weight and fruit yield compared to control and individual application of these nutrients. The combined application of both organics and inorganics significantly increased the ascorbic acid compared to 100% RDF alone (Shashidhara 2000). Vermicompost in combination with chemical fertilizers significantly increased growth attributes of chilli compared to organic manure and chemical fertilizers alone (Hangarge et al. 2001). 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 in chilli (Hossain et al. 2001). 100 kg N ha recorded the highest plant height (94.00 cm), number of branches per plant (37.00), leaf area index (0.93), total dry matter production (102.00 g^{-1} plant) and its distribution in different plant parts compared to the application of 75, 50 and 25 kg N ha^{-1}. A significantly higher uptake of N, P and K was also recorded with the application of 100 kg N ha^{-1} over control (Malagi 2001). Nanthakumar and Veeragavatham (2001) also recorded significantly higher ascorbic acid content in brinjal over control due to application of crop residues. The highest fruit yield (19.12 q ha^{-1}) with the application of 200% RDF + FYM (10 t ha^{-1}) + vermicompost (2.5 t ha^{-1}). Among 13 treatments 100% N as poultry manure

was found to be best for high keeping quality. 75% N as poultry manure + 25% N as chemical fertilizer was having high vitamin C. Poultry manure proved to be the best and among various combinations (1:1 ratio of chemical fertilizer and organic manure) found to be the best for increasing the yield and quality of chilli (Sharu and Meerabai 2001). Nirmal Kumar et al. (2003) revealed the effect of nutrients on chilli, nitrogen was highly pronounced and other nutrients like P, K, S and Zn were effective on number of fruits per plant, fresh yield as well as dry yield of chilli. Highest number of fruits per plant, fruit weight, fruit length and fruit diameter of chilli was obtained by applying vermicompost alone as compared to inorganic fertilizers (Yadav and Vijayakumari 2003). The application of FYM @ 10 t ha^{-1} along with RDF increased oleoresin content and quality parameters over 100% RDF alone (Santoshkumar and Shashidhara 2006).

Application of 100% RDF @ 100:50:50 kg N: P_2O_5: K_2O ha^{-1} recorded maximum 100 fruit weight (86.30 g) and yield (702.00 kg ha^{-1}) of chilli genotype Byadagi dabbi besides recording higher uptake of N, P and K (36.30, 5.10 and 27.20) kg ha^{-1}, respectively. The quality parameters like oleoresin per cent increased by 13.89, 6.60, 3.70 and 2.30% with application poultry manure @ 7.50 t ha^{-1}, vermicompost @ 10 t ha^{-1}. FYM (50%) + vermicompost (50%), FYM (50%) + neem cake (50%), respectively over RDF alone (Santoshkumar and Shashidhara 2006). The extractable color value also increased by 2.90 to 6.00% with application of FYM (50%) + poultry manure (50%), FYM (50%) + neem cake (50%) over RDF alone (Thimma Naik 2006). Bell pepper variety US Agri 181 showed higher yield followed by Aishwarya and California wonder for integrated nutrient management (Gopinath et al. 2008). Application of glyricidia loppings @ 10 t ha^{-1}, crop residues @ 10 t ha^{-1} along with FYM + organic solutions significantly increased the growth parameters of chilli compared to inorganic fertilizers (Yadahalli 2008). NPK and FYM at four different levels, yield per plant significantly increased as the concentration varies (Dorji et al. 2009). Application of organics viz., farm yard manure (FYM) along with 100% recommended dose of fertilizer (RDF) resulted in higher fruit yield (919 kg ha^{-1}) than RDF alone and increased by 16%. Application of FYM @ 10 t ha^{-1} along with 100% RDF enhanced the uptake of nutrients like N, P and K by 14.1, 44.9 and 37.4%, respectively over RDF (Kattimani et al. 2009) . With respect to quality of green chillies, ascorbic acid, capsaicin, oleoresin and moisture content in green chilli were higher in organic manure 100% (composted coir pith 25% + vermicompost 25% + bio-digested slurry 25% + Azospirillum-PSB 25%) (Naveen et al. 2009). Integrated use of vermicompost @ 5 t ha^{-1} + 150% RDN showed the maximum plant height, plant spread, number of fruits per plant, days to 50% flowering, weight of 100 fruits, fruit set and yield ha^{-1} (Surya Kumar et al. 2009).Dual inoculation with the biological nitrogen fixers (Azotobacter and Azospirillum), 100% recommended dose of N-fertilizer @ 80 kg N ha^{-1} and farmyard manure @ 15 t ha^{-1} recorded maximum growth, yield (7.43 tonnes ha^{-1}) and quality parameters and cost : Benefit ratio of 1.55 and no significant difference was observed when N-fertilizer level was reduced to 75%. Thus, associative nature of the above biofertilizers helped to save 25% nitrogenous fertilizer in chilli crop. There was increased content in plant nitrogen (84.10 mg kg^{-1}), phosphate (84.42 mg kg^{-1}) and potash (57.46 mg kg^{-1}), leaf chlorophyll (0.204 mg 100 g^{-1}) and residual available soil nitrogen (202.90 kg ha^{-1}), phosphate (67.10 kg ha^{-1}) and potash (70.50 kg ha^{-1}) with dual inoculation with the biological nitrogen fixers along with full dose of N-iertilizer (Talukder and Jana 2009). 3% novel organic liquid fertilizer application resulted in maximum plant height, number of branches per plant, leaf number, leaf area, fresh and dry weight of the plant, number of fruits per plant and total yield (Deore et al. 2010).

Treatment of nitrogen 125 kg ha^{-1} + FYM @ 10 t ha^{-1} Azospirillum reported more plant height, number of branches per plant, days to first 50% flowering, days to first harvest, number of fruits per plant, weight of individual fruit, fruit length and diameter, yield of wet red fruits (Deshpande et al. 2010). The treatments comprised of foliar sprays of humic acid @ 50, 100 and 200 ppm with and without FYM. Foliar spray of 100 ppm humic acid with and without FYM exhibited significant effects on nutrient uptake, yield and quality parameters. Thus, application of foliar spray of 100 ppm humic acid along with soil application of FYM for chilli found better under pot culture. The study revealed that the application of 100% RDN through urea (50% at time of transplanting and 50%

one month after transplanting) and full recommended dose of P_2O_5 and K_2O at the time of transplanting recorded significantly highest values of plant height (80.73 cm), east west and north-south plant spread as (53.33 and 52.26 cm), respectively, mean number of primary branches (7.33), leaf area (5.83 dm^2), number of fruits (168.26) per plant, fruit girth (1.06 cm), fruit length (8.60 cm) maximum ascorbic acid content (66.52 mg 100 g^{-1}) and yield (7958.0 kg) per hectare (Medhe et al. 2010). The extracts of different organics of neem cake, mustard cake, FYM, groundnut cake, poultry manure, press mud, castor cake and coconut cake were tested against *F. solani* by poisoned food technique in *in vitro*. Least growth of the pathogen was recorded in the extracts of neem cake showing excellent inhibitory effect i.e. 59.8% against *F. solani*. Next best in order of merit was mustard cake (52.61%) followed by FYM (49.40%), groundnut cake (44.80%), poultry manure (42.29%), and least by other cakes (Yelmane et al. 2010). Application of green manure (sun hemp) + neem cake @ 2 t ha^{-1} + *Azospirillum* @ 2 kg ha^{-1}+ burnt ash (crop residue) + phosphobacteria recorded higher growth parameters like plant height, plant spread, number of branches per plant of chilli over RDF alone (Bharathi et al. 2011). Growth, yield and fruit quality of sweet pepper hybrid SH-SP-5 was affected by integration of inorganic fertilizers and organic manures and nitrogen @ 150 kg ha^{-1}, phosphorus @ 120 kg ha^{-1}potassium @ 60 kg ha^{-1} and FYM @ 40 t ha^{-1} proved better to improve the growth and yield attributing traits (Malik et al. 2011).

The plant height was more in 1.5% amino acid micronutrients chelate solution and number of branches per plant was more in 2% amino acid micronutrients chelate solution at the flowering stage and leaves and leaf area per plant, fruits per plant and fruit length, fresh fruit weight and total yield per plant were more in 2% amino acid micronutrients chelate solution (Datir et al. 2012). Among 12 treatments yield was more in 50% NPK + 50% FYM + biofertilizers, 50% NPK + 50% pig manure + biofertilizers, 50% NPK + 50% vermicompost + biofertilizers and maximum available N (305 kg ha^{-1}) content after harvest was observed under 100% NPK (90:60:60 kg ha^{-1}) in King chilli (Vimera et al. 2012). Cultivar Pusa Jwala showed significantly higher growth, yield and quality parameters with the inoculation of biological nitrogen fixers like *Azospirillum* and *Azotobacter* (Khan et al. 2014). The combined effect of nitrogen and potassium and the maximum plant height and number of fruit per plant were highest in treatment containing 75 kg ha^{-1} N + 60 kg ha^{-1} K (Bhuvaneshwari et al. 2013). Among different combinations of organic manures and inorganic fertilizers, vermicompost along with 50% urea showed maximum plant height, number of branches per plant and qualitative aspects were increased with the application of neem cake compared to other inorganic sources (Pariari and Khan 2013). Nitrogen @ 180 kg ha^{-1} and potassium @ 50 kg ha^{-1} has positive effect on growth and quality parameters (Khan et al. 2014). Yield of dry chilli was highest with the application of organic manures (Patil et al. 2014). Among 12 different treatments 50% NPK + 50% FYM + bio fertilizers showed more nutrient status of soil after harvesting of crop. NPK and organic carbon content were more compare to all other treatments. Apart from this the pH of soil was 4.9 where all other treatments showing less pH than this, so by this one can conclude that FYM and bio fertilizers are having positive effect on soil health (Samsangheile and Kanaujia 2014). Combined application of 150 kg N ha^{-1} along with 10 t FYM and 0.5 t neem cake ha^{-1} had significant increase in plant height, canopy spread, number of branches per plant, number of fruits per plant, yield per plant and total green chilli yield (Leela Rani et al. 2015). Panchagavya along with organic manures showed significantly enhanced microbial population and crop growth in legumes and different cropping system (Monika Rana et al. 2015). In paprika, application of vermicompost (250 g^{-1} plant) combined with neem cake (100 g^{-1} plant) recorded higher growth parameters, yield and quality attributes, which was comparable with inorganic fertilizers at the recommended levels. Under integrated nutrient management, application of 75% N (8 g^{-1} plant) + *Azospirillum* spp.(5g $^{-1}$plant)+75% P (1.7g^{-1} plant)+ phosphobacteria (5 g per plant) + 100% K (2.5 g per plant) improved the growth, yield and quality parameters of paprika a like chillies as compared to recommended NPK through fertilizers indicating a saving 25% of both inorganic N and P through biofertilizers (Shiva et al. 2015). Application of 25 t FYM ha^{-1} along with RDF (100:50:50 NPK kg ha^{-1}) recorded higher plant height, similar trend was also noticed in days to 50% flowering, higher number of fruits, fruit length, fruit diameter,

seed weight over control (Vikash Kumar et al. 2016).

Organic amendments

Among liquid manures, the combined application of jeevamrut + panchagavya and beejamrut + jeevamrut recorded significantly higher dehydrogenase activity over control which might be due to presence of naturally occurring, beneficial microorganisms in panchagavya that improve soil quality (Xu and Xu 2000). At Indian Grassland and Fodder Research Institute, Jhansi Research was conducted with various jaivic and vedic krishi inputs such as angara, amritpani, panchagavya and gomuthra the results revealed that all the jaivic and vedic krishi inputs improved the crop productivity, soil microbial population and soil biological activity (Sadanandan and Drand 2006). Somasundaram and Singaram (2006) analyzed panchagavya to know its composition which was found to contain total N (302.00 mg kg^{-1}), total P (218.00 mg kg^{-1}), total K (355.00 mg kg^{-1}), total sugars (205.00 µg ml^{-1}), glucose (6.00 mg dl^{-1}), sodium (96.00 mg kg^{-1}), calcium (27.00 mg kg^{-1}), total organic carbon (0.80%), IAA (9.15 mg kg^{-1}), GA (4.00 mg kg^{-1}), phenols (0.75 µg ml^{-1}) bacteria (34 × 106 cfu ml^{-1}), fungi (22 × 104 cfu ml^{-1}), *Actinomycetes* (3 × 1012 cfu ml^{-1}), *Pseudomonas* (45 × 103 cfu ml^{-1}), yeast (35 ×104 cfu ml^{-1}), lactic acid bacteria (22 ×106 cfu ml^{-1}), methylotrophs (5 × 103 cfu ml^{-1}), *Azospirillum* (2 × 102 cfu ml^{-1}), *Acetobacter* (43 ×103 cfu ml^{-1}),ammonium oxidizers (24 × 105 cfu ml^{-1}), nitrite oxidizers (2 × 102 cfu ml^{-1}), pH (5.62), EC (10.3 dS m^{-1}), Zn (0.26 mg kg^{-1}), Fe (0.83 mg kg^{-1}), Mn (0.23 mg kg^{-1}) and Cu (0.2 mg kg^{-1}). Jeevamrut contains enormous amount of microbial load which multiplies in the soil and acts as a tonic to enhance microbial activity in soil (Palekar 2006). Yadav and Christopher (2006) reported significantly higher net returns with panchagavya spray over no panchagavya spray. However, B:C ratio was also higher with combined application of RDF and panchagavya (2.28) over RDN through organics + panchagavya spray in rice Combined application of fermented organics viz., beejamrut, jeevamrut, panchagavya along with organics such as compost, vermicompost and green leaf manure recorded the higher soil biological activity. Similarly, dehydrogenase activity was higher with combined application of organics and fermented organics than their individual applications and RDF + FYM. The highest dehydrogenase activity was observed with compost + vermicompost + green leaf manure + jeevamrut + beejamrut and was at par with the treatment receiving vermicompost + green leaf manure + jeevamrut + beejamrut + panchagavya. The lowest dehydrogenase activity was noticed with the application of RDF + FYM at 60 DAS of soybean in soybean-wheat cropping system (Shwetha and Babalad 2008). Among 10 treatments, 50% RDN + 50% N through FYM + BF + panchagavya was found best for higher dry chilli yield, total dry matter production, number of fruits per plant per picking, maximum ascorbic acid content in green fruits, maximum color value in red fruits (Kondapanaidu et al. 2009). Dipping the chilli seedlings root in beejamruth, soil application of jeevamruth (500 liter ha^{-1}) at 10 DAT and foliar application of panchagavya @ 3% at the time of flowering recorded higher ascorbic acid and capsaicin content in chilli fruits (Sreenivasa et al. 2010). The treatment of panchagavya along with vermicompost enhanced the growth parameters like length of plant, number of branches, number of fruits and size of fruits as compared to the plants which were grown on vermicompost alone (Rao et al. 2014). The concentration of the panchagavya is gradually increased like 25, 50, 75 and 100%. The plant growth, leaf length, leaf weight, root length and chlorophyll content were showing gradual positive response as the concentration of panchagavya increases (Ponnumani and Semmalar 2015).

Different nutrient management practices on the benefit cost ratio of chilli

Higher net returns with combined application of organics and inorganics over inorganics alone in chilli (Santoshkumar and Shashidhara 2006). By economic analysis the marginal rate of returns (MRR = The profit for every additional one unit) were greater when applying 2 t of FYM along with NPK of 8-6-6 kg ac^{-1}, 16-8-8 kg ac^{-1} and 24-18-18 kg ac^{-1}. Applying 4 and 8 t of FYM along with three doses of NPK was not economical (Dorji et al. 2009). Bell pepper variety US Agri 181 showed high benefit cost ratio of 9.2 compared to Aishwarya and California wonder (Gopinath et al. 2008). Among 10 treatments he found 50% RDN + 50% N through FYM + BF + panchagavya showed

highest B:C ratio (1.78) (Kondapanaidu et al. 2009). Dual inoculation with the biological nitrogen fixers (*Azotobacter* and *Azospirillum*), 100% recommended dose of N-fertilizer @ 80 kg N ha^{-1} and farmyard manure @ 15 tonnes ha^{-1} recorded maximum growth, yield (7.43 tonnes ha^{-1}) and quality parameters, and cost: benefit ratio of 1.55 and no significant difference was observed when N-fertilizer level was reduced to 75% (Talukder and Jana 2009). 100% RDN through urea, (50% at time of transplanting and 50% one month after transplanting) and full recommended dose of P_2O_5 and K_2O at the time of transplanting, showed maximum benefit : Cost ratio of 4.68:1 (Medhe et al. 2010). The benefit cost ratio for chilli cultivar Byadagi Dabbi and found highest with the application of 10 t FYM and benefit cost ratio was 2.53 (Shivaprasad et al. 2010). Naik et al. (2012), concluded that the benefit cost ratio was 1.83 for organic chilli cultivation and that of inorganic chilli was 1.35. Among 12 treatments yield was more in the most profitable treatment was (50% NPK + 50% FYM + biofertilizers) which gave the highest net return of Rs 571 thousand with B:C of 6.19:1 followed by 544 thousand with B:C of 5.75 : 1 in (50% NPK + 50% pig manure + biofertilizers) (Vimera et al. 2012). Benefit cost ratio of 2.5 : 1 and high net income with the application of 150 kg ha^{-1} nitrogen along with 10 t FYM and 0.5 t neem cake (Leela Rani et al. 2015).

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