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A review on drip fertigation technology in hybrid chilli (*Capsicum annuum* L.)

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ABSTRACT

Chilli is an important vegetable crop of India and is grown for its pungent fruits, which are used both green and ripe to impart pungency and colour to the food. India is the largest producer, consumer and exporter of chilli. The yield of chilli under conventional method of cultivation is very low and it can be increased by improved agronomic practices. Among the agronomic practices, nutrient management plays a vital role in determining the yield and quality of chilli. Fertigation is a recent innovative method, by which fertilizers are applied along with irrigation water through drip system to get higher fertilizer use efficiency besides increased yields. Chilli crop requires a balanced fertilizer management for normal growth and development of the crop. It is a heavy feeder of nutrients and higher yield can be sustained only through the application of nutrients at optimum doses in balanced proportion. Moreover, the nutrient requirement of hybrid chilli is high as compared to varieties, which also varies with the growth stages of the crop. Among the various factors responsible for high yield, the use of appropriate quantity of nutrients at proper time plays a vital role in enhancing the productivity. Hence, planning the nutrient supply according to the phenological stages of development may result in high yield with quality produce. In this context, fertigation technology plays a key role to achieve higher productivity and nutrient efficiency.

Key words: Chilli, drip fertigation, nutrient use efficiency, yield, fertilizers.

Application of water soluble or liquid fertilizers through irrigation water is known as fertigation. By definition, fertigation is the precise application of water soluble fertilizers through sprinkler and drip irrigation (Billsegars, 2003). It is an efficient and agronomically sound method of providing soluble plant nutrients directly to the active plant root zone. The increasing area under micro-irrigated crops provides an excellent opportunity to explore new methods of providing complete and balanced plant nutrient programmes that have the potential to improve plant health and increased yields. Fertigation permits improved efficiency of irrigation and nutrient usage and reduces application costs. It improves plant growth and nutrient uptake and limits nutrient losses. Applying fertilizer through the irrigation system has several advantages:

- Nutrients can be applied at any time during the season
- Amount and concentration of nutrients can be as per crop requirement
- Nutrients are applied uniformly near the growth site of the crop (near the crop)
- Reduced fluctuations of nutrient concentration in the root zone
- Enhanced fertilizer use efficiency and fertilizer saving
- Reduced nutrient leaching
- Increased yield and quality of farm produce
- Saving of time, labour and cost of application
- Uniformity of application
- Crop damage during fertilizer application is minimized (FAO, 2005)

Feigin *et al.* (1982) reported that fertigation is the most efficient method of fertilizer application. This decreases leaching and volatilization losses, improves the nutrient utilization efficiency and minimizes ground water contamination. Drip fertigation enables accurate adjustment of water and nutrient supplies to meet the crop requirement (Papadopoulos, 1988). Drip fertigation permits application of nutrients directly at the site of high concentration of active roots (Sivanappan *et al.*, 1987). Drip irrigation with fertigation may reduce the risk of crop damage due to a high water table coupled with heavy rains. Fertigation allows nutrient placement directly in to root zone during critical periods of nutrient demand. Deshmukh *et al.* (1996) reported that 30 per cent of NPK fertilizers can be saved by the use of liquid fertilizer through drip irrigation system in comparison with recommended fertilizer levels applied conventionally under flood irrigation. Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, reduces over all fertilizer application rate and minimizes the adverse environmental impact. A properly designed drip fertigation system delivers water and nutrients at a rate, duration and frequency, so as to maximize crop water and nutrient uptake, while minimizing leaching of nutrients and chemicals from the root of crops.

Scheduling of fertigation

As plants grow, their demand for nutrients change and as such, some nutrients that are easily taken up by plants may get depleted sooner than the exclude dones. This preferential uptake of solutes can lead to high concentrations of the excluded salts in the rhizosphere that could prove to be detrimental for optimum plant growth. Thus fertigation is often necessary to augment nutrient fertilizer. A fertigation scheduling plan is often compounded by the changing demands of fertilizer requirements of growing plants. Nevertheless, fertigation should be carried out, not to adversely alter the solute dynamics in the root zone, but should provide tolerant and optimum concentration of nutrients and salts in the rhizosphere. Hence, accurate prediction of when and how much fertilizer to apply is critical for fertigation management. The amount of fertilizer to be applied depends on the plant requirement. The frequency of application for fertilizers depends on the soil type, system design constraints, and the length of the growing season. The frequency of fertigation is usually not as critical as achieving the right rate of application at a given crop stage.

Effect of fertigation on growth, yield and quality Chilli and capsicum

Storlie *et al.* (1995) studied the effects of fertilizer rates and application frequency on drip fertigated chilli and found that yield and fruit quality were the greatest with 71.82 kg N, 31.36 kg P and 56.54 kg K acre^{-1} in sandy loam soil. Average marketable fruit weight increased with increasing fertilizer rate. Bracy *et al.* (1995). In a study conducted by Muralidhar (1998), three methods of irrigation *viz*., furrow, drip and fertigation each in combination with 80 and 100 per cent water soluble or normal fertilizers were compared for growth and yield of chilli. The growth was superior with fertigation as the growth components *viz*., plant height, leaf area, number of leaves and primary and secondary branches were improved by fertigation, which eventually resulted in significantly higher dry matter production at all growth stages. Green fruit yield was the highest with fertigation compared to drip and furrow irrigation methods. The highest fruit yield of capsicum hybrid Green Gold was obtained with 100 per cent fertigation using water soluble fertilizers. The highest yield was the result of better plant growth coupled with yield components like more number of marketable fruits plant^{-1} and higher fruit size (Prabhakar and Hebbar, 1999). Sureshkumar (2000) reported that application of 100 per cent dose of water soluble fertilizers outweighed its lower level of 75 per cent dose in terms of yield. Drip fertigation with polyfeed (19:19:19+MEN) was found to be an efficient system of fertilizer application over conventional fertilization in terms of nutrient use efficiency. Prabhakar *et al.* (2001) found that fertigation with half dose of NPK (100:100:100 kg ha^{-1}) and black polythene mulch resulted in the highest yield (12.13 t ha^{-1}) with higher fruit weight, number of fruits per plant and number of clusters per plant. They also found that the highest fruit yield of 30.4 tonnes ha^{-1} was recorded when polyfeed (19:19:19 NPK) was fertigated along with foliar spray of 0.5 per cent polyfeed three times in the growing season. Veeranna *et al.* (2001) found that drip fertigation of water soluble fertilizers at 80 per cent recommended dose produced significantly higher dry fruit yield of 1268 kg ha^{-1} over all other treatments.

Fertigation of recommended dose of fertilizers (100:50:50 kg NPK ha^{-1}) at two days intervals up to 105 days resulted in significantly higher yield of green chilli of 9.30 and 9.06 t ha^{-1}, during first and second year of the crop (Tumbare and Nikam, 2004). Muralikrishnasamy *et al.* (2006) showed that drip irrigation at 50 per cent pan evaporation and 100 per cent N and K through fertigation recorded 67.47 per cent increased dry pod yield (2222 kg ha^{-1}) compared to surface irrigation (1327 kg ha^{-1}) with entire NPK as soil application. Prabhu (2006) studied the effect of fertigation on paprika and found that 100 per cent recommended dose of water soluble fertilizers in combination with micronutrients under open condition registered the highest values for morphological characters like number of primary branches per plant, specific leaf weight, leaf dry weight and total dry matter production at different phases of crop growth.

Selvakumar (2006) studied the performance of drip fertigation with 100, 80 and 60 per cent water soluble fertilizers with reference to growth and yield of chilli. The growth was the highest with fertigation as the growth components like plant height, leaf area and primary and secondary branches were improved, which eventually resulted in significantly higher dry matter production at all growth stages. Green and dry fruit yield were the highest with fertigation compared to surface irrigation methods. Mahajan *et al*. (2007) indicated that water and N application through drip irrigation in red hot pepper increased yield, water use efficiency and nutrient use efficiency. Nitrogen at 100 per cent recommended dose, supplied through drip irrigation system, increased the red hot pepper yield to 277.4 q ha^{-1} with an increase of 28.4 per cent over check basin irrigation (216.1 q ha^{-1}).

Gupta *et al*. (2010) revealed significant improvement in yield, quality and water and fertilizer use efficiencies of capsicum under drip irrigation and fertigation. The treatment combination of 80 per cent ET through drip and 80 per cent recommended NPK through fertigation registered the highest fruit yield (366.48 q ha^{-1}). However, the fertilizer use efficiency was found the highest (NUE - 4.8 q kg^{-1} N; PUE - 6.53 q kg^{-1} P; KUE - 9.79 q kg^{-1} K) with the treatment combination of 80 per cent ET through drip and 60 per cent recommended dose of NPK through fertigation.

Tomato

Singandhupe *et al*. (2003) showed that the highest tomato fruit yields of 27.4 and 35.2 t ha^{-1} in two years were recorded at 120 kg N ha^{-1}. At the highest level of applied nitrogen (120 kg N ha^{-1}), total average N uptake during two years were found to be 64.5 and 104.7 kg ha^{-1}. The apparent N recovery was 82.5 per cent at 48 kg N ha^{-1} in comparison with 47.9 per cent at 120 kg N ha^{-1}. Hebber *et al*. (2004) showed that fertigation with water soluble fertilizers recorded significantly higher total dry matter production and leaf area index (181.9 g and 3.69 respectively) over drip irrigation. Fertigation with 100 per cent water soluble fertilizers increased the fruit yield significantly over furrow irrigated control and drip irrigation.

Drip irrigation along with fertigation of 100 per cent recommended nitrogen resulted in increase in fruit yield by 59.5 per cent over control (recommended practices) inside the greenhouse and by 116.8 per cent over control (recommended practices) outside the greenhouse. The net profit and yield mm^{-1} of water used were estimated to be the highest for the treatment of drip irrigation in conjunction with fertigation of 125 per cent of recommended nitrogen among different treatments (Mahajan and Singh, 2005).

Kavitha (2005) reported that the yield parameters like number of fruits per plant, fruit weight and polar diameter were the highest at 100 per cent water soluble fertilizers under shade. The highest yield per hectare (99.8, 109.5 and 106.7 tonnes) during season I, II and III respectively were observed in the treatment with water soluble fertilizers under shaded condition. Soumya *et al*. (2005) stated that significantly higher marketable fruit yield was recorded with the application of 100 per cent recommended dose of NPK (94.50 t ha^{-1}) with the higher water use efficiency of 143.11 kg ha^{-1} mm^{-1}. Balasubramaniam (2008) opined that drip-fertigation has an advantage of favourable physiological, biochemical, nutritional and growth attributes that eventually enhanced the final yield of tomato to the tune of 26 per cent in comparison with conventional system.

Shyamaa *et al*. (2009) reported that higher level of fertigation was found significantly concerning growth parameter and fruit yield. Fertigation with 100 per cent NPK water soluble fertilizers increased tomato fruit yield significantly (58.76 t ha^{-1}) over furrow irrigated control, drip irrigation, 50 per cent fertigation and 75 per cent NPK fertigation. In tomato, Gupta *et al*. (2010) observed that the yield parameters like number of fruits, fruit length, pericarp thickness and fruit yield were the highest at fertigation treatment. The highest yield per hectare (989.3 q ha^{-1}) was found in the treatment with combination of 80 per cent ET through drip and 60 per cent recommended dose of NPK through fertigation. Sanchita *et al*. (2010) found that fertigation of water soluble fertilizers at 100 per cent recommended dose of N and K produced significantly higher fruit yield of 85.53 t ha^{-1} than soil application of 100 per cent recommended dose of NPK in tomato (59.71 t ha^{-1}).

Brinjal

Borrelli (1980) reported that application of water soluble fertilizers resulted in the highest cumulative yield of 40 t ha^{-1} with higher rates of 7:21:21 compound fertilizer. Jainu *et al*. (1987) observed that in trickle irrigation, yields were the highest (822 g $plant^{-1}$) with 180 kg N ha^{-1}, while in furrow irrigation, yields were the highest (202 g plant^{-1}) with 360 kg N ha^{-1}. The fertigation irrespective of the combination of fertilizers, was superior to soil application in terms of yield (Papadopoulos and Leena, 2000). In brinjal, Aujla *et al.* (2007) reported that the highest yield (103.10 kg ha^{-1}) under fertigation was obtained at $N_{120,}$ which was 23 per cent higher with the saving of 30 kg N ha^{-1} as compared to the highest yield obtained at furrow irrigation with N_{150}.

Potato

Papadopoulos (1988) found that the highest yield (58.13 t ha^{-1}) of good quality potatoes was obtained with 130 mg l $^{-1}$ N, which was adequate for maintaining NO_3^- N level of petioles. In another trial, Papadopoulos (1992) showed that application of P (40 g mg l^{-1}) resulted in no accumulation of P in deep layers of soil profile, which was recommended for obtaining high yields of good quality tubers. Stark and McCann (1992) obtained the highest yield in the case of Russet Burbank cultivar of potato when N was applied at 132 kg ha^{-1}. Among the split applications a weekly application at 44 kg week^{-1} was the best to produce the highest yield and to maintain NO_3^-N. Amarananjindeshwara (1997) reported that the total marketable tuber yield of potato was higher (22 t ha^{-1}) under fertigation with 100 per cent water soluble fertilizers than the conventional method. Singh *et al.* (2004) compared trickle fertigated treatments with conventional method of fertilizer application in potato and found that parameters like leaf area, dry matter accumulation and yield attributes were higher in P-fertigated crop than furrow irrigated and conventional method.

Other vegetables

Shinde *et al.* (2010) showed that significantly higher values of parameters were recorded with 100 per cent recommended dose of nitrogen (100 kg N ha^{-1}) through fertigation with eight splits. The length, girth and density of fruits were increased with increase in fertilizer levels and number of splits, while fruit weight did not show any remarkable difference. Number of fruits per plant (10.40) and yield of fruits (2.166 kg plant^{-1}) were significantly higher with 100 per cent recommended dose of fertilizers through drip irrigation with eight splits. Sanchita *et al.* (2010a) reported that application of 100 per cent PE with 100 per cent recommended dose of nitrogen (200 kg N ha^{-1}) through fertigation was found to be significantly superior in terms of growth and yield of broccoli. Fertigation with a total input of 200 kg N ha^{-1} was sufficient to produce the highest yield of 20.36 t ha^{-1}.

Effect of fertigation on nutrient uptake
Nitrogen

Haynes (1991) observed higher N uptake in green fruit (37 kg N ha^{-1}) and above ground portion (89 kg N ha^{-1}) and 4.3 per cent of leaf nitrogen content with application of 75 kg N through fertigation in green pepper. Olsen *et al.* (1993) revealed that total uptake of N, P, K, Ca, Mg and S by capsicum was increased with increased application of N. The capsicum plants that received fertigation had higher leaf nitrate concentration and yielded more than three times those plants that received fertilizer prior to planting (Obreza and Vavrina, 1995). Makswitat *et al.* (1995) reported that the total uptake of N was much lower in pickling cucumbers which took up 411 kg N ha^{-1}. Pan *et al.* (1999) opined that fertigated plants had higher uptake of N at 28 days after transplanting, which contributed to higher relative growth rate of the plants with drip irrigation. Fink and Scharpf (2000) reported that the total uptake of nitrogen varied from 220-411 kg ha^{-1} and the uptake by fruit was between 105 and 287 kg ha^{-1}. Tumbare and Nikam (2004) observed that application of recommended dose of fertilizers at every irrigation (2 days intervals) up to 105 days recorded significantly higher uptake of nitrogen (104.69 kg ha^{-1}) than surface irrigation (87.30 kg ha^{-1}).

Phosphorus

Olsen *et al.* (1993) reported that the total uptake of N, P, K, Ca, Mg and S by bell pepper was increased with increasing application. Higher leaf tissue P content in tomato was observed under application of 75 kg P ha^{-1} through drip fertigation (Carrijo and Hochmuth, 2000). Veeranna *et al.* (2001) showed that the phosphorus uptake was the highest (11.17 kg ha^{-1}) in 100 per cent RDF with water soluble fertilizers and the lowest uptake recorded was 6.52 kg ha^{-1} in furrow irrigation. Selvakumar (2006) reported that phosphorus uptake varied due to different levels of fertilizer dose and significantly higher uptake under 100 per cent RDF; whereas the lowest uptake was recorded with the lowest level of fertilizer dose (40 per cent RDF) in chilli. According to Shyamaa *et al.* (2009) in tomato, the phosphorus uptake was significantly higher (18 kg ha $^{-1}$) in 100 per cent fertigation than drip irrigation and furrow irrigation.

Potassium

Veeranna *et al*. (2001) stated that the uptake of nutrients in chilli was significantly influenced due to fertigation and conventional method of fertilizer and water application. Fertigation of 80 per cent recommended dose with WSF registered 73.67, 11.83 and 53.27 kg ha^{-1} N, P_2O_5 and K_2O uptake over furrow irrigation. Meenakshi (2002) reported that water soluble form of macronutrients (MAP and MK) and micronutrients (Polyfeed – 19:19:19) recorded the highest yield in bitter gourd hybrid COBgoH-1. Tumbare and Nikam (2004) stated that application of recommended dose of fertilizers at every irrigation (2 days intervals) up to 105 days recorded significantly higher uptake of potassium (99.10 kg ha^{-1}) than surface irrigation (44.60 kg ha^{-1}). Application of 100 per cent recommended dose of NPK through water soluble fertilizers (Polyfeed 19:19:19) recorded the highest yield in tomato hybrid Ruchi (Kavitha, 2005).

Effect of fertigation on fertilizer use efficiency

Fertigation reduces the nutrient loss that would normally occur with conventional methods of fertilizer application and thus permits better availability and uptake of nutrients by the crops, leading to higher yield with high fertilizer use efficiency. Nitrogen use efficiency for red chilli fruit production decreased with increasing N up to 240 kg ha^{-1} (Payero *et al*., 1990). Fertilizer use efficiency is an important factor that needs to be taken into consideration in agricultural production systems as inefficient use of fertilizer inputs leads not only to an environmental hazard but also a substantial economic loss. Generally, the fertilizer use efficiency by crops is in the range of 50 – 70 per cent for N, 10 – 25 per cent for P and 50 – 60 per cent for K. Shyamaa *et al*. (2009) stated the fertilizer use efficiency was significantly superior in all the drip irrigation treatments. This was due to better availability of moisture and nutrients throughout the growth stages in drip and fertigation system leading to better uptake of nutrients and production of tomato fruits. FUE was significantly higher in 100 per cent fertigation (138) compared to drip irrigation (103), 50 per cent fertigation (114) and 75 per cent NPK fertigation (127 kg kg^{-1} NPK).

Effect of biofertilizers on growth and yield

Paramaguru and Natarajan (1993) observed that in chilli cultivars Local and CA-42 inoculated with *Azospirillum* in combination with 75 per cent of recommended nitrogen produced higher plant height (56.13 and 57.86 cm, respectively) and the highest number of primary branches (6.3 and 5.9, respectively). Dutta and Ramadass (1993) observed that in chilli and tomato, the chlorophyll content, NAR, RGR, leaf area and fresh weight of leaves were significantly increased in the plots inoculated with *Azospirillum*.

Kacheri and Korla (2009) registered that application of biofertilizers showed increase in plant height, curd size, leaf area, number of leaves and curd yield in cauliflower. Arulkumar (2010) reported that the drip fertigation of 100 per cent RDF (50 per cent NPK as basal +50 per cent through drip) exhibited the highest protein content (18.25 mg g^{-1}), ascorbic content (18.52 mg g^{-1}) and mucilage content (1.82 per cent) and the least crude fibre content (10.74 per cent) in bhendi.

Cost economics of fertigation

Among the methods of water and fertilizer application, fertigation resulted in higher gross and net returns and the highest benefit cost ratio of 4.80, followed by drip (3.81) and furrow method (3.47) in capsicum (Muralidhar, 1998). Khan *et al*. (1999) found that drip fertigation with 100 per cent water soluble fertilizers in potato recorded higher net profit of Rs. 38,742 ha^{-1} compared to drip fertigation with 100 per cent straight fertilizers (Rs. 33,604 ha^{-1}) and furrow irrigation with 100 per cent straight fertilizers (Rs. 32,583 ha^{-1}). Kavitha (2005) reported that application of 100 per cent water soluble fertilizers under shade secured the highest net return with the highest benefit cost ratio of 2.90, 3.13 and 3.18 during season I, II and III respectively in tomato. Drip irrigation with 100 per cent recommended dose of fertilizers registered the highest net income of Rs.1, 23, 679 ha^{-1} and BCR of 3.30 in chilli (Selvakumar, 2006). Muralikrishnasamy *et al*. (2006) reported that the highest BC ratio was 1.87 in drip irrigation at 75 per cent PE and 100 per cent N and K through fertigation compared to higher levels of irrigation and fertigation in chilli. Balasubramanian (2008) observed that the economics worked out on drip fertigation in tomato 'US 618' revealed that the drip fertigation recorded a benefit cost ratio of 4.25 compared to conventional system, which recorded 1.60.

Gupta *et al*. (2010) reported that the highest BC ratio was 3.31 in the treatment combination of 80 per cent ET through drip and 60 per cent recommended dose of NPK through fertigation compared to higher levels of irrigation and fertigation in tomato. Sanchita *et al.* (2010) stated that application of 100 per cent recommended dose of N and K water soluble fertilizers through fertigation recorded the highest net return with the highest benefit cost ratio of 2.28 in tomato. Shinde *et al.* (2010) showed that 100 per cent recommended dose of fertilizers through fertigation with eight splits recorded the highest net return (Rs. 71465 ha-1) and benefit cost ratio (3.34) in cucumber. Sanchita *et al.* (2010a) reported that fertigation with 100 per cent recommended dose of N (200 kg ha^{-1}) was the most efficient treatment with fertigation efficiency of 57.31 per cent and cost benefit ratio of 4.14 in broccoli.

CONCLUSION

Nutrient management is the most important agrotechnique, which controls growth, yield and quality of a crop. Nutrient use efficiency is only 50 per cent in conventional practices of soil application. Sustainability of any system requires optimal utilization of resources such as water, fertilizers and soil. Apart from the economic considerations, the adverse effect of injudicious use of water and fertilizers on the environment can have far reaching implications. There is a need to standardize agrotechniques, which will help in sustaining the precious resources and maximizing crop production, without any detrimental impact on the environment. Location specific nutrient management practices are essential for increasing nutrient use efficiency besides optimizing the fertilizer input and maximizing the productivity and profitability.

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