Review Article

Drip Fertigation in Vegetable Crops for Higher Crop Productivity and Resource Use Efficiency - A Review

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Abstract

Water and fertilizer are the two major inputs for vegetable production and they are interrelated in their effects on plant growth, yield and quality of vegetable crops. Since, water and fertilizer are costly inputs, every effort must be taken to enhance the water and fertilizer use efficiency by reducing their wastage. Drip fertigation, a technique of application of both water and water soluble fertilizers via a drip irrigation system have been found to be very effective in achieving the higher water and fertilizer use efficiency in vegetable crops. In this method both water and fertilizer are delivered precisely and uniformly to the crop root zone as per the crop needs and according to crop developmental phase. By adopting drip fertigation, it is possible to increase the yield potential of vegetable crops by three fold with the same quantity of water. Besides, it has also been found to improve the quality of crop produce, helps the grower to get better price of their produce. The water and fertilizer saving through drip fertigation have been reported to be 40-70 and 30-50 per cent, respectively.

Keywords: Drip fertigation, Vegetable crops, Productivity, Resource use efficiency, Economic feasibility

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Introduction

Vegetables are important constituents of Indian agriculture and nutritional security due to their short duration, high yield, nutritional richness, economic viability and ability to generate on-farm and off-farm employment. India is blessed with diverse agro-climatic conditions with distinct seasons, making it possible to grow wide array of vegetables. Water and fertilizer are the two major inputs for successful vegetable production and they are interrelated in their effect on plant growth and yield. Besides, sustained higher yield with high yielding varieties depends entirely on the sustainable use of the limited water and energy resources, specifically in arid and semi-arid regions where water scarcity is a major problem. Since, water and fertilizer are costly inputs, every effort must be taken to enhance water and fertilizer use efficiency by reducing their wastage. In recent years drip fertigation – a technology of application of both water and water soluble fertilizers through a drip irrigation system was shown to be very effective in achieving higher water and fertilizer use efficiency. Fertigation allows application of right amounts of plant nutrients uniformly to the wetted root volume zone where most of the active roots are concentrated, reduces the leaching losses and thus helps in achieving the higher nutrient use efficiency. Besides, it has also been found to improve the productivity and quality of crop produce along with improved resource use efficiency [16]. Fertigation saves fertilizers up to 25 per cent [37] thus fertigation results in appropriate and efficient use of costly inputs such as water and fertilizer. Therefore, drip fertigation is an important concept and the key focus of this article is to discuss the importance and potential of drip fertigation technology for higher crop productivity and resource use efficiency in vegetable crops.

What is fertigation?

Fertigation is a technique of fertilizer application in which fertilizer is incorporated within the irrigation water by the drip system where timing, amounts and concentration of fertilizers applied are easily controlled. Fertigation ensures saving in fertilizer (40-60%), due to "better fertilizer use efficiency" and "reduction in leaching" [19]. In present conditions, water has become scarce natural resource due to rapid industrialization, population growth and urbanization. There is urgent need to reduce the consumption of water in irrigation as irrigation utilizes the major fraction of available water by developing new irrigation efficient technologies and methods that could help to utilize

precious input in an effective way. Drip irrigation is one of the efficient methods of irrigation having about 90 per cent water use efficiency. It is a type of micro-irrigation that has the great potential to save water and nutrients by allowing water to drip slowly to the roots of plants minimize evaporation. In the conventional method of fertilizer application, a considerable portion of the applied fertilizer may not be available to the crop as majority of nutrients are lost or fixed in the soil as they come in contact with a large mass of soil and thereby reducing the nutrient availability to crop. Fertigation through drip irrigation reduces the wastage of water and chemical fertilizers, optimizes the nutrient use by applying them at critical stages and at proper place and time, which finally increase the water and nutrient use efficiency. Moreover, it is well recognized as the most effective and profitable means of maintaining optimal nutrient level and water supply according to crop development stage, specific needs of crops and type of soil.

Significance of fertigation

Deficiency of N, P and K is a major production constraint in sandy soils, which leads to constraints like P fixation, rapid hydraulic conductivity, faster infiltration rate, leaching of basic cations and low CEC. Hence, the cultivated crop in this soil requires large quantity of nutrients to support its growth and yield. Considering the soil and crop constraints, nutrients should be applied in synchrony with crop demand in smaller quantities during the growing season. The right combination of water and nutrients is a prerequisite for higher yield and good quality of produce. The method of fertilizer application is also important in improving the use efficiency of nutrients. Fertigation helps in adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand. Besides, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses [21]

Fertigation scheduling

Factors that affect fertigation scheduling are soil type, available NPK status, organic carbon, soil pH, soil moisture at field capacity, available water capacity range, aggregate size distribution, crop type and its physiological growth stages, discharge variation and uniformity coefficient of installed drip irrigation system. The efficient fertigation schedule needs the following considerations *viz*.

- Crop and site specific nutrient management,
- Timing nutrient delivery to meet crop needs and
- Controlling irrigation to minimize leaching of soluble nutrient below the effective root zone.

In fertigation nutrients can be injected daily or bimonthly depending upon system design, soil type and farmer's preference. Frequent injection may be needed for sandy soil with poor water and nutrient capacity and grower who want to reduce injection pump size and cost. Fertilizer should be injected in a period such that enough time remains to permit complete flushing of the system without over irrigation. The higher efficiency of water application reached in drip irrigation systems is ideal for the high efficiency of applied nutrients in fertigation. But, some of these potential benefits can reverse into disadvantages when the irrigation design or management is not correct which may leads to non-uniform nutrient distribution, over-fertigation, excessive leaching, clogging.

Effect of Drip Fertigation on Plant Growth, Yield and Quality of Different Vegetables

Tomato

Amala and Syriac [1] recorded the maximum dry matter production (219.42 g per plant), fruit set per cent (62.77), and fruits per plant (33.67) and fruit yield (42.36 t/ ha) of tomato at 125 per cent recommended dose of N and K through drip fertigation. A fruit yield of 45.7 t/ ha was obtained in tomato with application of recommended dose of fertilizers using polyfeed (19:19:19), MAP (12:60:0) and urea through fertigation, which was 22-27 percent higher compared to the crop provided with ordinary fertilizers through soil application [24]. Rana *et al*. [27] found that drip fertigation with 100 % recommended NPK increased growth parameters as well as yield and also enhanced the quality characters like TSS, titratable acidity, ascorbic acid content, fruit weight etc. as compared to conventional methods. An experiment was carried out by Brahma *et al*. [7] to find out the effect of N & K fertigation level of through drip irrigation on growth, marketable yield, fruit quality and economics of semi-determinate tomato cultivar Arka Abha. Results indicated that plant height (97.20 cm), branch number (12.20) , fruit setting percentage (74.65), fruit number per plant (49.34) and marketable yield (85.53 t/ha) were maximum with 100 per cent fertigation of recommended dose of N & K at the rate of 75 and 60 kg/ha, respectively. Gupta *et al.* [13] carried out a research for improving yield, quality and water/fertilizer use efficiency in tomato hybrid SH-TH-1 under drip irrigation and fertigation technology at the experimental farm of Division of Olericulture, SKU-AST-K, Shalimar, Srinagar. They

found higher TSS (4.920 brix) and Total sugar (3.77%) under I_2F_2 treat-ment *i.e* 80 percent ET through drip irrigation + 80 percent RFD through drip irrigation. The higher tomato yield and quality in drip fertigation is possible because water and fertilizers are applied in a gradual and uniform form directly to the roots, in sync with the crop demand, without wetting the plants [14][32]

Potato

Sasani *et al.* [29] revealed that application of 80 percent of recommended dose of N and K_2O through drip fertigation is the most efficient in obtaining significantly higher total tuber yield of 420 q/ha as compared to application of recommended dose of N and K_2O in furrow irrigation. It also resulted in better fertilizer use efficiency by savings 40 percent water and labour. Ghiyal and Bhatia [11]studied the effect of different nitrogen levels 90(N1), 120(N_2), 150(N_3) and 180(N_4) kg/ha and three fertigation frequencies, i.e. every 3rd day (F_1), every 6th day (F_2) and every 9th day (F_3). The per cent plant emergence at 30 (96.33 percent) DAP, plant height at 60 (49.63cm) DAP, number of shoots per hill at 30 (4.43), 60 (4.68) and 90 (4.68) DAP, leaf area index at 30 (1.21), 60 (6.02) and 90 (5.24) DAP and foliage weight (1.21 kg /m^2) were significantly higher with F_1 whereas the maximum value for per cent plant emergence at 30 (96.89 percent) DAP, plant height at 60 (49.83 cm) and 90 (54.98 cm) DAP, number of shoots per hill at 60 (4.64) DAP, leaf area index at 30 (1.17) and 90 (5.14) DAP, foliage weight (1.17 kg/m^2) and total tuber yield were maximum with N_2.

Brinjal

In brinjal, highest yield of 42.33 t/ ha was recorded in drip irrigation at 75 percent of recommended N and K with maximum shoot length and number of branches per plant when compared to other levels of irrigation and fertigation[40] .Different irrigation and nitrogen application levels were compared in brinjal where the highst yield (wh ich wa s 23% higher) was obtained at 75% of surface irrigation and 120 kg nitrogen per hectare with the saving of 25% water and 30 kg N /ha as compared with furrow irrigation [3]

Capsicum

Significant improvement in yield and quality of Capsicum under drip irrigation and fertigation was observed at Experimental Farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K) by Gupta *et al*. [12]. The combined effect of drip irrigation and fertigation was found superior than their individual effects. The treatment combination of 80 percent irrigation through drip and 80% recommended NPK through fertigation registered maximum fruit yield of 366.48 q/ha. Roy *et al*. [28] found that the length and width of fruit and number of fruits per plant increased significantly with increasing nitrogen doses up to 100 kg N/ha. However, average weight of fruit increased significantly with increasing levels of P up to 150 kg N/ha. Average weight of fruit and yield increased significantly with increasing levels of P up to 30 kg P/ha, whereas length of fruit and number of fruits per plant was increased significantly up to the 60 kg P/ha. Considering the combined effect of nitrogen and phosphorus, the maximum yield was recorded in the treatment combination of 150 kg N and 30 kg P /ha.

Chilli

Veeranna *et al.* [39] reported that 80 per cent water soluble fertilizer (WSF) is effective in producing about 31 and 24.7 per cent higher chilli fruit yield over soil application of normal fertilizers at 100 per cent recommended dose in furrow and drip irrigation methods, respectively, with 20 per cent of saving in fertilizers. Singh *et al.* [35] recorded highest yield of 15.94 t ha-1 with 75% RDF through fertigation + 2 foliar spray of 1% urea phosphate as compared to 50 per cent RDF through fertigation. A field experiment was conducted to investigate the effect of drip irrigation and nitrogen fertigation on yield of chilli (*Capsicum annuum* L.). The maximum yield (10.20 kg/m^2), net income, weed incidence, minimal diseases and saved water and total irrigation time was achieved due to fertigation as compared to top dressing method. All the yield contributing attributes were significantly influenced due to nitrogen fertigation. The fertigation of nitrogen had recorded 34.46 percent higher yield as compared to top dressing method. Increase in yield with higher level of nitrogen fertilizer might be due to higher amount of nitrogen availability for promotion of better carbohydrates utilization to form more protoplasm and cell and also due to readily available nitrogen in the vicinity of the root zone due to fertigation resulting in more efficient utilization of applied nitrogen than top dressing.

Cabbage and Cauliflower

At Rahuri, Maharashtra, India Kadam *et al*. [17] conducted an experiment on cauliflower cv. Golden 80 applied with 60, 80, 100, 120 and 140 percent of recommended NPK dose through drip system. They found that fertigation with 80 percent of the recommended NPK rates resulted in the highest plant survival (98.03 percent), plant height (95.9 cm), crop yield (554 q/ha) and the minimum number of days required to harvest curds. Vasu and Reddy [38] observed that daily fertigation of N and K (100% recommended dose) resulted in highest cabbage yield (16.92 t ha-1) and was also associated with higher content of N (3.18 percent) and K (4.60 percent). However, the highest head diameter (14.40cm), TSS (4.66 percent) and ascorbic acid (118.37 mg/100 g) content was observed with at 125 percent RDF. Kumar *et al*. [20] reported that increasing the irrigation and nitrogen levels increased the yield of cabbage significantly and highest yield (30.60 ton/ha) was obtained with drip irrigation at 100 per cent PE and fertigation with 150 per cent of recommended dose of nitrogen (29.71 t/ha) as compared to furrow irrigation at 1.2 IW/CPE (22.55 t/ha). Kapoor *et al*. [18] found that increase in NPK fertigation level from 33.3 to 100 percent RDF significantly increased number of leaves, relative leaf water content, marketable yield of cauliflower and benefit cost ratio but decrease in fertilizer expense efficiency.

Broccoli

An experiment was conducted by Brahma *et al* [8] on broccoli (*Brassica oleracea* L. var. *italica*) cv. Pusa Broccoli KTS1 to study the effect of different levels of nitrogen fertigation on growth, yield and economics of the crop. The results revealed that there was significant improvement in growth, yield and fertilizer use efficiency of broccoli under drip irrigation and fertigation. Drip fulfillment at 100 percent evaporation replenishment with cent percent supplementation of recommended dose of nitrogen (200 kg/ha) through fertigation was found to be significantly superior in terms of growth, yield and economics of broccoli in comparison to the conventional fertilization with recommended dose of nitrogen.. Singh *et al* [34] reported 115.37 and 17.32 per cent increase in broccoli yield with fertigation over drip irrigation and check basin method, respectively. Selim *et al.* [31] reported that application of humic substances through fertigation increased total marketable yield and head diameter of broccoli as well as quality parameters (*i.e.*, total soluble solids, protein and vitamin C).

Okra

Jadav *et al.* [15] observed tallest plants, more leaves per plant, higher leaf area and dry matter production with the crop fertigated through subsurface drip with 75 % recommended dose of nitrogen (RDN) over band placement of 100 % RDN with furrow irrigation. Rajput and Patel [25] conducted a fertigation trial in okra with 40, 60, 80 and 100 per cent RDN through drip and 100 percent RDN by broadcasting with furrow irrigation. The results of the study revealed that drip fertigation was superior over broadcasting in terms of enhancing yield contributing attributes and yield. Application of 60 % RDN through drip fertigation recorded comparable pod yield with that of 80 and100 percent RDN, which indicates a saving of nitrogen upto 40 per cent.

Cucumber

In cucumber drip irrigation coupled with fertigation showed significant advantages in terms of yield and economic returns compared to overhead irrigation and conventional fertilization practices under protected cultivation [4]. Ningaraju and joseph [22] recorded highest growth parameters and yield attributes with 200 per cent RDF and highest fruit yield of 72.4 tonnes per hectare was obtained by drip fertigation with the 100 percent Ep combined with 200 per cent of recommended dose of fertilizer. Chand [9] found that plants which received 100 percent of recommended dose of fertigation (175:125:300kg NPK ha-1) showed significantly higher yield (89.06 t /ha). In an field experiment conducted by Patil and Gadge [23] growth attributes, days to 50 per cent flowering, average diameter of the fruit, average length of fruit, average weight of fruit, length of vine were recorded and were significantly influenced by fertigation. Application of 125 per cent NPK through drip irrigation recorded maximum yield of 21.87 t/ ha followed by application of 125 per cent N through drip irrigation and soil application P and K as basal dose of a 21.61 t/ ha . Shinde *et al*. [33] found that growth attributes, number of leaves, vine length, number of primary branches, dry matter accumulation per plant, days required for first flowering and internodes at which first flower appear were significantly influenced by levels of nitrogen and number of splits and significantly higher values of these parameters were recorded with 100 percent recommended dose of nitrogen (100 kg N/ha) through fertigation with 8 splits.

Onion

Savitha *et al.* [30] investigated the effect of drip fertigation at 75, 100 and 125 percent in two varieties viz. Agrifound Dark Red (big onion) and COOn5 (aggregatum onion) and compared with the soil application of recommended dose of fertilizer. The results showed that in big onion var. Agrifound Dark Red, the fertigation with 75 per cent recommended dose of fertilizers (i.e., 75: 112.5: 56.25 kg of NPK ha-1) registered higher bulb yield (10.30 and 12.70 t ha -1) similarly in small onion var. COOn5, the fertigation with 75 per cent recommended dose of fertilizers (i.e., 45: 45: 22.5 kg of NPK ha-1) registered higher bulb yield (8.34 and 11.05 t ha-1) compared to soil application of fertilizer. Bhakare and Fatkal [5] stated that application of 125 per cent recommended dose of water soluble fertilizer with fertigation gave the highest yield of onion seed and improved the yield contributing parameters such as plant height, number of umbels per plot, number of umbels per plant, diameter of umbel and reduced the time to 50% flowering, but the yield was at par with 100 per cent recommended dose of water soluble fertilizers with fertigation. The treatment 75 per cent RDF through fertigation was significantly superior to application of 100 percent RDF through conventional fertilizer and there was a saving of 25 per cent of the added fertilizer. Dingre *et al.* [10] showed that drip fertigation resulted into 12 to 74 per cent increase in the productivity of onion seed as compared to conventional method. Rajput and Patel [25] recorded the highest onion yield in daily fertigation followed by alternate day fertigation and lowest yield was recorded in monthly fertigation frequency.

Drip fertigation and Resource use efficiency

Fertigation enables application of various nutrients and fertilizer formulations directly at the site of active roots in desired concentration and thus improves the nutrient use efficiency [2] Gupta *et al.* [13] in tomato reported the highest water use efficiency (29.40 q ha-1-cm) was observed with the treatment combination of 60 percent ET through drip + 80 percent recommended NPK through fertigation. The fertilizer use efficiency was found maxi-mum (NUE-4.89 q kg-1 N, PUE-6.53 q kg-1 P and KUE-9.79q kg-1 K) with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation. Kadam *et al.* [17] reported the higher WUE (18.95 q ha-1-cm) and FUE (230.9 kg ha-1) with 80 per cent of the recommended dose of NPK rates through fertigation as compared to other treat-ments. In broccoli an experiment was conducted by Brahma et al (2010) in Assam and found that fertigation saved fertilizers to the tune of 40 percent as compared to conventional fertilization to maintain the same yield levels in broccoli and they revealed that fertigation with cent percent recommended doses of N was the most efficient treatment with fertigation efficiency of 55.44%. Shinde *et al.* [33] found in cucumber that drip method of irrigation showed lower values of water requirement with an improvement in water use efficiency (10.13 q/ha cm.) whereas the maximum FUE was observed with 100 per cent NPK through drip irrigation system (68.73 kg/kg) by Patil and Gadge [23] . Rajput and Patel [26] observed that drip fertigation in bhendi has resulted in higher nitrogen use efficiency (70 kg / kg N) over broadcasting of nitrogen (48.7 kg / kg N). Bhanu and Mahavishnan [6] reported the water and fertilizer saving by 40-70 and 30- 50 percent, respectively through drip fertigation in lady's finger. In an experiment by Chand [9] plants that received 100 per cent recommended dose of fertigation (175:125:300 kg NPK ha-1) showed higher nutrient use efficiency of nitrogen, phosphorous and potassium (508.93, 712.50, 296.88 kg ha-1 respectively) and recorded significantly higher yield (89.06 t/ ha) with highest water use efficiency (6167.78 kg ha-1 cm-1).

Economic feasibility of Drip fertigation in vegetables

Net returns and Benefit cost ratio are the most important economic parameters to access the profitability of any treatment and the ultimate goal of any treatment is to achieve profit in terms of net return and B: C ratio. Under drip fertigation system, highest benefit cost ratio (2.17) in chilli was achieved with the application of 100 per cent recommended NPK [36]. Brahma *et al.* [7] studied on fertigation efficiency and economics of tomato and reported that fertigation with 100 per cent recommend-ed dose of N and K was the most efficient treatment with Fertigation efficiency of 43.24 per cent and cost: benefit ratio of 1:2.28. In cucumber Shinde *et al.* [33] found that application of 100% recommended dose of nitrogen through fertigation with 8 number of splits recorded the maximum net returns (Rs. 71465.6/ha) with benefit cost ratio of 3.34. Savitha *et al.* [30] investigated the effect of drip fertigation at 75%, 100% and 125 % in two varieties viz. Agrifound Dark Red (big onion) and COOn5 (aggregatum onion) and compared with the soil application of recommended dose of fertilizer. The economic analysis indicated that application of 75 per cent RDF a straight fertilizers viz., Urea, SSP and SOP through fertigation recorded the highest benefit cost ratio than the other treatments and it was adjudged to be the best nutrient management practice for both the onion varities. In broccoli, economic analysis by Brahma *et al*. [8] revealed that percent recommended doses of N was the most efficient treatment with benefit cost ratio of 1:4.41 and concluded that fertigation with the percent recommended dose

of N (200kg/ha) at 4 days interval corresponding to 21 drips can be practiced for profitable cultivation of broccoli (1:4.41) under the agro-climatic condition of Jorhat (Assam).

Conclusion

From the foregoing review it can be concluded that drip fertigation helps in proper utilization of fertilizers, saves labour and increases the productivity of vegetable crops. Apart from higher yield, higher resource use efficiency, higher benefit cost ratio is also obtained in drip fertigation. Drip irrigation cum fertigation increases the yield due to higher nutrient uptake and thereby improves water and fertilizer use efficiency. In turn fertilizer could be saved to the tune of 25 to 50 per cent through drip fertigation.

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