Fertigation in Fruit Crops

Deepika Singh and Neelam Kumari*

Dr Y S Parmar University of Horticulture and Forestry Nauni Solan, H.P. (173 230), India

Corresponding Author

Neelam Kumari
e-mail: neelkumari90@gmail.com

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Abstract

Fertigation has the greatest potential for the efficient use of water and fertilizers. Drip irrigation facilitates maximum water and nutrient efficiency by reaching the active root zone, and thus minimizing the wetting area. Adding fertilizer to drip irrigation reduces the costs associated with irrigation and fertilizer application. Additionally, fertigation minimizes the losses of nutrients through leaching. In this article, different aspects of fertigation are reviewed, including its impact on nutrient content in leaf and soil, tree growth, yield as well as quality of fruits. It clearly demonstrates the advantages and benefits of fertigation over conventional soil fertilization in terms of comparable or better tree growth, yield and fruit quality, as well as in terms of achieving considerable savings in the amount of water and fertilizer used. In fertigation, nutrient use efficiency could be as high as 90% compared to 40–60% in conventional methods.

Keywords: Fertigation, fertilization, fruit quality, nutrient use efficiency, tree growth, yield

1. Introduction

Fertigation is the use of combination of drip irrigation and fertilizer to create a controlled nutrient release system resulting in significantly lower leaching losses of nutrients while meeting the water and nutrient requirements of crops throughout their growing stage. This method permits application of nutrients directly at the site of active root zone and as per the crop requirements (Elfving, 1975). Several authors have pointed out the economic and agronomic advantages of fertigation especially, in fruits crops (Bussi et al., 1991; Battilani, 1997; Raina, 2000).

The conventional practice of fertilizer and irrigation application has given detrimental effect on the soil health and quality of produce besides, its poor nutrient and water use efficiency. The fertigation may lead to decrease in the cost of cultivation and improves the quality of fruits. Irrigation and fertilizers are the most important inputs which directly affect the plant growth, development, yield and quality of produce. Fertilizers applied through broadcasting method are not efficiently utilized by the plants whereas; fertigation ensures application of fertilizers directly into the site of active root zone. Fertigation offers vast potential for more accurate and timely crop nutrition leading to an increased yield and quality besides considerable saving in fertilizers (Raina, 2002). Fertigation is, therefore, necessary to increase productivity and fruit quality. Fertigation system has resulted in the saving of water up to 40% and fertilizer up to 30% in peach production system (Hasan et al., 2004). Lack of assured irrigation water and improper nutrient management are some of the major factors contributing to low production of fruits. Under such conditions, the available nutrient contents are not utilized efficiently by the plants, when applied through conventional methods. Steep slopes, undulating topography, shallow soil depth, poor water retention further aggravates the problem, consequently leading to low yields.

Nitrogen is the nutrient element most commonly applied through drip irrigation system and is often injected as urea and ammonium salt which has been found to improve the yield and quality of fruits (Haynes, 1985). Few reports on nitrogen fertigation through drip system in peach (Bussi et al., 1991), plum, cherry and apple (Michael et al., 1979; Buban and Lakatos, 2000) have been documented. Generally, all the nitrogen fertilizers are suitable for drip fertigation except ammonium sulphate (NH_4SO_4) which may cause precipitation of calcium sulphate ($CaSO_4$) in hard calcium rich water. Urea is well suited for injection through drip irrigation since it is highly soluble and dissolves in non-ionic form and does not react with substances in the water. Nitrate salts are characteristically soluble and are well suited for use in drip irrigation.

2. Effect of Fertigation on Tree Growth

Application of fertilizers through drip irrigation not only resulted in conservation of water but also created favorable plant growth conditions. Fertigation has shown positive influence on tree height, canopy cover and girth. The comparable yields recorded under fertigation with 60% of recommended dose and soil fertilization with 100% of recommended dose suggested that nitrogen saving to an extent of 40% can be achieved through fertigation. The best balance between increased shoot growth, fruit bud production, fruit set and cumulative yield was achieved with fertigation at 20 g N tree^{-1} (26 kg N hac^{-1}) in apple (Hipps, 1992). Fertigation at 40 and 80 g N tree^{-1} caused increase in total shoot growth associated with an excessive production of axillary floral buds that absconded leaving unproductive bare wood. Increase in trunk girth and shoot growth was recorded with fertigation in apple (Bhardwaj et al., 1995; Goode and Ingram, 1971). The effect of banded fertilizer, low fertigation and high fertigation on tree growth and vigour in peach was studied and maximum trunk cross sectional area was observed under drip irrigation (Richard et al., 1996).

The pre-bearing vegetative growth of acid lime plant and leaf nitrogen content were found to be optimum under nitrogen fertigation treatments. The plant height increased by 31% in 100% N fertigation treatment followed by 30% in 80% N fertigation treatment and 100% N band application treatment. The plant girth increased 52.3% in 100% N fertigation followed by 80% N fertigation (49.2%), band placement (49%) and 60% N fertigation (45.4%). The percentage increase in canopy volume was more in 100% N fertigation treatment (48.2%) followed by 80% N fertigation (46.9%). The growth of the acid lime plant was optimum in 80% N fertigation treatment (Shirgure et al., 1999). The higher growth parameters under fertigation compared with conventional soil fertilization may be ascribed to the higher nutrient efficiency and less weed incidence coupled with minimum leaching losses (Yosef, 1999).

The plant height, canopy cover and plant girth showed overall positive influence of drip fertigation in lemon. Maximum increase (28.4%) in average plant height was recorded in 8 split doses of urea @ 30 g N plant^{-1} at 13 days interval, justifying the beneficial effects of frequent split applications of N over surface application of fertilizers. A similar trend was observed in canopy cover and plant girth, giving maximum values of percentage increase as 154% and 100%, respectively (Gaur and Kumar, 2003). The fertigation with different amounts of nitrogen had no consistent effect on tree growth, cumulative yield and yield efficiency in apple. However, treatments had a significant influence on regularity of bearing. The natural tendency of apple cv. "Elstar" of alternate bearing was overcome by application of different rates of nitrogen through fertigation (Cmelik and Tojnko, 2004).

An experiment was conducted to study the efficacy of NPK management through fertigation on growth characteristics of apple cv. Red Chief. Highest vegetative growth of plants was found under full dose of NPK through drip irrigation in terms of shoot length (111.43 cm), plant diameter (2.87 cm), number of leaves plant^{-1} (223.50), leaf area (43.19 cm^2), fresh weight (2.33 g) and dry weight of leaves (62%), while the minimum shoot length (84.48 cm), plant diameter (1.97 cm), number of leaves plant^{-1} (178.25), leaf area (27.43 cm^2), fresh weight (1.10 g) and dry weight of leaves (35%) were noticed under full dose of NPK applied through soil. The full dose of NPK through fertigation also resulted in maximum leaf N (2.565%), P (0.282%) and K (1.685%) and gave maximum chlorophyll 'a' (0.51 mg g^{-1} tissue), chlorophyll 'b' (0.40 mg g $^{-1}$ tissue) and total chlorophyll content (0.92 mg g^{-1} tissue) (Singh et al*.,* 2007). Maximum fruit yield of guava (*Psidium guajava* L.) (16.9 t ha^{-1}) was registered at 100% of recommended dose of N (Sharma et al., 2013).

A field experiment was conducted to study the effect of N and K fertigation on growth, yield and leaf nutrient status of almond (*Prunus dulcis*) in Srinagar, Jammu & Kashmir, India. Maximum tree height (3.21 m and 3.56 m), nut weight (2.73 g and 1.94 g) and nut yield (2.41 kg tree^{-1} and 5.98 kg tree^{-1}) were observed with 75% recommended dose of fertilizers through fertigation (split application) (Kumar and Ahmed, 2014). Increase in the number of fruits tree^{-1} and fruit yield was observed when sweet orange plants were supplied with N and K at 75% recommended dose through fertigation (Venkata Ramana et al., 2014). Fertigation with recommended dose of NPK gave significantly higher plant height (24.23 cm), leaf area (129.20 cm^2) and fruit yield (35.64 t ha^{-1}) of strawberry cv. Chandler as compared to fertigation with ½ and $^1/_3$ of recommended dose of NPK and soil fertilization but was at par with ¾ recommended dose of NPK fertigation treatment (Kachwaya and Chandel, 2015).

3. **Effect of Fertigation on Fruit Quality**

The efficient use of water and fertilizers through fertigation to improve the fruit quality is important concern in today's horticultural system. Fertigation appreciably improved the fruit yield and quality over conventional soil fertilization. A slight increase in calcium concentration of apple fruits was observed from the plots fertigated with calcium nitrate without any influence on firmness and storage behavior ((Neilsen et al., 1993). The higher nitrogen concentration in leaves and fruits after fertigation was common and resulted in less skin colour development (Ericson, 1993). The effect of fertigation on the mineral composition of apple fruits and their colour was also studied by Dolega and Link (1998). Total seasonal application of N early in the season resulted in earlier fruit maturity or larger fruit size in Navel orange (Kallsen, 1999). Irrigation and partial fertigation (15% of total NK) reduced both soluble solids and acid concentration in Valencia orange. Partial fertigation had a minimal effect on fruit production, compared with use of dry fertilizer alone (Koo and Smajstrla, 1985). Fertigation resulted in higher nutritional status (N, P and K content), leaf N and K content, physiological efficiency (total chlorophyll content), photochemical efficiency, stomatal conductance, net photosynthesis, water use efficiency and fruit quality of pawpaw (Jeyakumar et al., 2001).

An experiment was conducted to determine the effect of fertigation comprising treatments: irrigation at 10, 20, 30 and 40% depletion of available water content and NPK fertilizers at 600:200:100, 500:140:70 and 400:80:40g on growth parameters of mandarin. Irrigation at 20% depletion of available water content and NPK fertilizer treatment of 500:140:70 were the optimum irrigation and fertilizer requirements, respectively. The combined application of these two treatments produced higher fruit yield m^{-3} of canopy, in addition to higher N, P, K and other fruit quality parameters (Srivastava et al., 2003). Combining high density plantation with fertigation was reported to give superior berry size, sugar content, skin colour and significantly higher yield of grapes as compared to traditional methods of irrigation and fertilization (Kurafuji et al., 2008).

A field experiment was conducted to study the response of microirrigation and fertigation on yield and quality of litchi cv. 'Rose Scented'. The maximum fruit set, fruit retention, fruit weight, fruit volume, fruit yield, ascorbic acid content with minimum fruit cracking were recorded under treatment bubbler discharge at 1.0V level+microsprinkler+125% level of fertigation (Singh et al., 2010). Fertigation significantly improved yield and quality characteristics of litchi in terms of maximum yield, fruit retention and minimum fruit drop (Yadav et al., 2011).

4. Effect of Fertigation on Leaf Nutrient Status

Drip fertigation provides an efficient way to allow an adequate, accurate as well as uniform application of fertilizers to the wetted area where the active roots are concentrated. This results in better physiological growth of plants with higher leaf nutrient status. A positive correlation was documented between irrigation and nutrient assimilation (Goode and Ingram, 1971). So far, as the varietal influence on leaf nutrient content irrespective of micro-irrigation levels is concerned, apple cv. Red Chief recorded significantly higher leaf N content whereas, maximum leaf Ca and Mg content was recorded in cv. Well Spur. While, maximum levels of Zn and Fe were recorded in cv. Starkrimson. In apple, standard fertilization gave higher nitrogen contents than fertigation whereas maximum leaf P content (2.10%) was found with fertigation as compared to standard fertilization (1.83%). There were greater differences in leaf K content with standard fertilization and with microjet irrigation (Cassagnes et al., 1984). An increase was observed in leaf nitrogen and magnesium concentration of apple plants fertigated with nitrogen whereas, phosphorus and potassium were found to be inversely related (Klein et al., 1989).

An experiment was conducted to investigate the effect of different rates of nitrogen through fertigation on the mineral composition of leaves and fruits of Sampion and Golden Delicious cultivars of apple. Leaf analysis showed that there were no significant effects of fertigation effects on leaf N, P, K, Mg and Ca (Zydlik and Pacholak, 1997). Reduction in leaf K was observed under drip fertigated apples which were attributed to restricted root development (Neilsen et al., 2000). Studies on effect of soil application and drip fertigation of fertilizers such as urea, single supper phosphate and muriate of potash and of water soluble fertilizers on grapes cv. 'Banglore Blue' revealed that soil application of 100% fertilizers and drip irrigation with 80% water soluble fertilizers registered highest mean potassium and calcium content in the leaf petiole of grapes (Murthy et al., 2001).

The leaf N concentration of Starkrimson and Cooper-IV apple cultivars grown on MM-106 rootstock was highest in plants receiving 13 g N+10 g P_2O_5+17 g K_2O and 15 g N+10 g P_2O_5+10 g K_2O through fertigation (Farooqui et al., 2005). Pear leaf N and P concentrations during autumn were increased by 10% and 10.6%, respectively, under split fertigation as compared to broadcast (Yin et al., 2009). Increase in leaf K, Mg and B contents and fruit N, P, Mg, K and Ca concentration was observed in apple plants in response to N and K fertigation (Neilsen et al., 2004).

5. Effect of Fertigation on Soil Nutrient Status

Sustainability of any production system requires optimal utilization of resources. Fertilizer is one of the most important farm inputs, which needs to be utilized most judiciously and efficiently. The nitrate form of N does not react with soil exchange sites and is not held in soils. Nitrates whether previously applied or added in drip irrigation system move with the soluble salts to the wetted front. Potassium, however, is less mobile than nitrate (Goode et al., 1978), but its distribution in the wetted soil volume may be more uniform due to interaction with binding sites. Phosphorus, in contrast to K, is readily fixed in many soils (Kafkafi and Bar-Yosef, 1980), although movement of applied P differs with soil texture. A variety of fertilizer formulations have been suggested for the use through trickle irrigation (Bruce et al., 1980). Since, their chemical characteristics differed; therefore, nutrients cannot be distributed uniformly in the soil when applied through trickle irrigation (Goldberg, 1971). Potassium fertigation of prune trees resulted in better K movement to a depth of 60-70 cm where the soil was wet and roots were abundant, thus enhancing K uptake (Uriu et al., 1980). Better movement of K under drip irrigation has also been observed by Guennelon and Cabibel (1981). A slight increase in soil pH in response to N fertigation was observed directly below the emitter (Haynes and Swift, 1987). More exchangeable Ca, Mg and K were displaced from below and around the emitter when ammonium sulphate was applied instead of urea as N source.

Studies on effect of nitrogen fertigation of "Starking Delicious" apple trees found that nitrate concentration in soil was raised proportionally to the N dose applied during 6 week fertigation period. The concentration of nitrate in 60-90cm layer under treatments comprising lower N doses was less as compared to upper layers. The reverse was the case with higher N dose. Potassium concentration decreased with soil depth. In 0−30 cm layer, it showed inverse relation with N dose which was attributed to NH_4-K exchange. During fertigation, K concentration in each soil layer under all treatments increased except for the lowest N dose in 30−60 cm layer, where insufficient NH_4 was available to displace K from the upper soil layer (Klein et al., 1989). N and K fertigation in apple allowed the movement of nitrogen to soil depths between 16 and 32 inches in a narrow cylindrical pattern with a horizontal diameter of 32 inches. When nitrogen was applied to the soil surface as a dry fertilizer it was concentrated mostly in the top 16 inches of soil (Robinson and Stiles, 2004). Fertigation of apricot cv. New Castle was reported to give higher NO_3–N content in the upper soil layers as compared to conventional soil fertilizer application (Raina et al., 2005).

An experiment was conducted to determine the effect of fertigation comprising different fertilizer application rates (25, 50, 75 and 100% of recommended dose) and frequencies (10, 20 and 30 days) on the distribution pattern of available phosphorus and potassium in arecanut. The concentration of both P and K was reported maximum at the dripping point within 30 cm depth and declined progressively with distance from dripping point. Nutrient distribution pattern showed that both 50 and 100% NPK levels maintained more or less similar available P and K concentration in the arecanut rhizosphere (Bhat et al., 2007). In an another experiment on nutrient distribution under drip irrigat ion in olive, highest concentrations of magnesium, iron, manganese, zinc and copper below the emitter was found especially in 0−20 cm depth (Shaaban and El-Fouly, 2005).

In a study on cantaloupe revealed that an appreciable amount of applied urea moved readily away from the water source and did not accumulate in the soil but continuously decreased with time after fertigation due to hydrolysis. Ammonium distribution was found restricted to a radius of 15−20 cm around the water source because of slow transport due to adsorption. In contrast to ammonium, nitrate accumulated at the boundary of the wetted area (50−70 cm) which proved that nitrate movement in the soil was directly proportional to the water movement. Phosphorus and potassium were found present only adjacent to the water source, mostly irrespective of irrigation method as both the elements are highly adsorbed by the soil preventing their movement further down the soil profile. Potassium moved to the lower soil depth due to successive irrigation close to the end of fertigation period (Badr, 2007). The content of nitrate nitrogen in the soil solution increased significantly only at a depth of 10 cm (Koumanov et al., 2009).

The above review of literature on fertigation has narrated many advantages like higher water and fertilizer use efficiency, minimum leaching losses, optimization of nutrient balance by supplying nutrients directly to the root zone, control of nutrient concentration in soil solution and cost effectiveness. Under fertigation, soil moisture remained greater in upper 0−30 cm of soil, whereas under conventional surface irrigation, deeper layers registered greater values.

6. Conclusion

This review concludes that fertigation resulted in greater growth and yield over conventional fertilization besides saving about 30% in irrigation water. High initial investment and comparatively low technical skill of average Indian farmers are some of the major constrains limiting the large scale adoption of drip fertigation technology in the country. However, increasing water scarcity and escalating fertilizer prices may lead to greater adoption of the technology especially in high value fruit crops.

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