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NPK fertigation of stone fruit crops: A review

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Abstract
Stone fruit crops play a significant role in the food and nutritional security. These fruits are mostly perennial in nature and require proper irrigation and fertilization for optimum growth, yield and quality. Nitrogen, phosphorus and potassium play a vital role in overall development of stone fruits. However, the use of these nutrients through conventional methods does not meet the fertilizer requirement according to the growth stage of the tree and thereby, fertilization becomes inefficient. Fertigation refers to application of fertilizers through irrigation, provided to an area of soil, where most of the active roots are present and also matches the timing of nutritional demand of the tree. Thus, efficient use of fertilizers and water thereby, minimizing leaching losses as compared to other methods of application. Taking into account, the declining water resources and leaching losses of fertilizers, it is essential to adopt such efficient technology to avoid scarcity in near future. The past studies conducted on different stone fruits suggested that adoption of this technology have improved the overall status, *viz.* growth, yield, quality and nutrient content of stone fruits, which is also highly beneficial to fruit growers from economic point of view.

Keywords: Stone fruits, NPK Fertigation, growth, yield, quality, nutrients status

Introduction

The term stone fruits is used to denote fruits of the *Prunus* species, *viz.* peach, nectarine, plum, cherry and apricot, which contain hard stony seed in the flesh. These are the most important fruits worldwide among fruiting tree species, which plays a significant role for small horticulturists and rural economies (Jacob, 2010) [45]. The area under stone fruits are rapidly increasing in temperate parts of world due to its rich nutritional and economic value. The interest in growing these crops under subtropical regions during the last three decade has also increased due to availability of high quality and low chilling cultivars (Sharpe *et al*., 1990) [81]. Nutritionally, stone fruits are good sources of vitamins and minerals and there is increasing interest in their potential value as nutraceutical due to the presence of phenolic compounds with antioxidant properties. Land and water are the two primary inputs for progress in horticulture and economic development of any country. Water is becoming increasingly scarce globally with the fast shrinking of irrigation resources and continued expansion of population in the world. Fertilization is another critical operation which directly govern the optimum production in any cropping system. Hence, the efficient use of water and fertilizers are major concern to increase fruit yield and quality in modern horticulture (Dinnes *et al*., 2002 and Dong *et al*., 2005) [24, 25]. Fertigation is one of the recent techniques of applying fertilizers through drip irrigation systems (Edwards *et al*., 1982 and Bussi *et al*., 1991 Hagin and Lowengart, 1996 and Srinivas, 2004) [26, 17, 36, 96], which permits the application of various fertilizer formulations directly at the site of roots and thus, improves fertilizer use efficiency (Singh *et al*., 2005 and Shirgure and Srivastava, 2014) [89, 84]. This technique had come into existence in the late 1960’s in Israel. (Goldberg and Shimueli, 1970; Magen, 1995 and Sneh, 1995) [33, 55, 93], however, the earliest study on fertigation was probably proposed by Bryan and Thomas (1958) [13].

In recent past few decades, many researchers after using this technique in different stone fruits have pointed out the advantages of fertigation than other means of conventional fertilization. In peach, fertigation significantly improved the tree growth, yield, physical and chemical properties of fruits (Patten *et al*., 1989; Bryla *et al*., 2003 and Banyal *et al*., 2014) [69, 15, 6]. The valuable effects of fertigation on yield attributes, leaf and fruit nutrient content, tree growth, nutrient use efficiency and chemical traits were observed in nectarines (Battilani, 1997; Krig and Stassen, 2008 and Singh *et al*., 2015) [9, 51, 88]. The fertigation treatments have been found significantly superior in terms of vegetative and reproductive growth, time of application and yield, nutrient, quality characters in cherry (Neilsen *et al*., 2010 and Salgado *et al*., 2012) [66, 77].

The higher water and fertilizer use efficiency and improved growth, physical, quality and leaf nutrients parameters in apricot (Bybordi, 2013) [19]. Advances in micro-irrigation techniques have emerged as greater application of fertigation in stone fruits. The stone fruits also serve as alternative source of nutrients which reduce the burden on per capita consumption of other food sources as most of the stone fruits are perennial in nature. A considerable amount of work has been carried out on fertigation, however, studies on performance of stone fruits under fertigation are very limited. This review presents a brief description about utility of fertigation and its significance in stone fruits including growth, yield, quality, nutritional value and also the physiological and biochemical mechanism responsible for uptake of these nutrients. Subsequently, which might create interest of grower towards cultivation of these fruits and fetching high economic value from same piece of land.

Benefits of fertigation in stone fruits

Precise water and fertilizer management are foremost step in intensive fruit orcharding to enable the manipulation of growth and physiological development of trees and to ensure the possibility of higher quality fruit with extended storage period and to minimize costs of production (Tagliavini and Marangoni, 2000) [98]. Fertigation satisfies both the crop needs and minimize nutrient losses. In last few decades, various researchers had observed significant economic and agronomic advantages of fertigation in different fruit crops (Goldberg and Shimueli, 1970; Elfving, 1975; Huguet, 1980; Gastoud *et al*., 1982; Haynes, 1985; Burt *et al*., 1998; Bar-Yosef, 1999; Smith, 2001; Battilani, 2008; Ashraf *et al*., 2012; Shirgure, 2012, Sharma *et al*., 2014; Shirgure and Srivastava, 2014 and Singh and Kumari, 2017) [33, 27, 43, 31, 39, 16, 8, 92, 10, 4, 82, 80, 84, 86], which will help fruit grower to understand vast utilities of fertigation.

The continuous supply of water and fertilizers to the trees would mean a freedom at all times from shortage of moisture and nutrients, respectively (Mishra and Pyasi, 1993 and Bar-Yosef, 1999) [59, 8], which would enable trees to attain higher growth rate, increased yield and nutrient uptake (Silber *et al*., 2003) [85]. As there is even supply of water soluble fertilizers to the trees, there is possibility of obtaining higher yield percentage (Brahmanand and Singandhupe, 2000; Solaimalai *et al*., 2005 and Malhotra, 2016) [12, 94, 56]. Under drip fertigation, where a portion of soil is wetted, water use efficiency is found to be increased up to 90 per cent (Wu, 1993; Sivnappan, 1994 and Manohar *et al*., 2001) [102, 90, 57] and fertilizer use efficiency is also higher which helps to save nutrients up to 80 per cent (Smith *et al*., 1979, Haynes, 1985, Tromp and Bolding, 1988; Fares and Abbas 2009; Imamsaheb *et al*., 2011; Sandal and Kapoor, 2015 and Srivastava and Malhotra, 2017) [91, 39, 99, 30, 44, 78, 97]. Precise application and uniform distribution of fertilizers in soil (Sathya *et al*., 2008) [79] and mineralisation of limited root zone are the main reasons for the reduced nutrient requirement (Magen, 1995) [55]. In this technique, fertilizers are supplied directly to the active root zone as required by the trees (Clark *et al*., 1991; Rajput and Patel, 2002 and Singh *et al.*, 2005) [23, 73, 89], which otherwise also eliminates the danger of burning the tree root system, since the fertilizer is applied in very low concentration. Nutrients and water losses due to volatization and evaporation are very minimum or completely absent because nutrient solution is supplied through network of pipe lines. Moreover, fertilization scheduling is done on the basis of crop need and hence, improve efficiency and flexibility than other methods of application (Rolston *et al.*, 1979; Raina, 2002; Chen *et al*., 2010 and Nanda, 2010) [75, 70, 21, 62]. Under fertigation, water and fertilizers are supplied at the right time and required levels. Thus, over-feeding is totally avoided and also helps to meet the physiological needs of the trees at different stages of growth (Li, *et al*., 2002 and Shirgure, 2013) [54, 83]. Combining water, liquid fertilizers with insecticides and herbicides (Kumar, 1999) [52] saves labour, machinery and time of application separately. The fertigation technique also gives benefits under saline water condition where relative high water potential develops between frequent irrigations and hence, salt concentrations remain low (Magen, 1995) [55]. Cultivation of stone fruit trees under light soil condition, always possess problem and hence, fertigation offers growing of these crops under such soil condition and also minimizing soil compaction by avoiding involvement of heavy traffic of equipment as in conventional method of fertilizer application and thereby, maintaining and improving the physical, chemical and biological nature of soil (Haynes and Swift, 1987) [41]. In conventional approaches, over fertilization and irrigation result in high intensity of weeds and pathogens, whereas, fertigation facilitate reduced weed population and contact time of pathogen with the tree (Yarwood, 1978 and Battilani, 2008) [103, 10]. Fertigation can be referred as spoon feeding approach of fertilization, where, fertilizer requirement of crop is calculated on the basis of individual tree demand for NPK on daily basis over the entire growing period of crop (Kabirigi *et al*., 2017) [47].

NPK fertilizers, migration and localization in the soil

Out of the 17 essential nutrients, nitrogen, phosphorus and potassium play a vital role in growth and development of many fruit crops as these are directly involved in various physiological processes of tree life cycle. Mass flow and diffusion along the concentration gradient are the main physiological processes that control movement of nutrients from the soil solution to the surface of root (Jungk, 1996) [46]. However, these mechanisms are affected by soil condition and crop characteristics. Nitrogen is comparatively more mobile nutrient and taken up by trees through mass flow, whereas, less mobile nutrients like phosphorus and potassium are absorbed by the process of diffusion (Barber, 1995 and Mmolawa and Or, 2000) [7, 60]. Transportation of both mobile and less mobile nutrients are facilitated by diffusion process, which under fertigation, becomes much more efficient mechanism of nutrient transport than mass flow (Claassen and Steingrobe, 1999) [22].

Nitrogen

Nitrogen (N) is one of the major plant nutrients, which often applied to obtain optimum crop production. Besides tree growth, it is also involved in a number of physiological functions (Singh and Singh, 2002) [87]. Because of the loss of its various forms through leaching, volatilisation, denitrification or fixation in the organic fractions of the soil, availability of nitrogen usually becomes limited in the soil than other nutrients and often applied through drip irrigation system. Delivery of nitrogen through fertigation reduces nitrogen losses in the soil tree system by ammonia volatilization and nitrate leaching (Smith, 2001) [92]. The application of nitrogen in one time or in bulk is likely to convert into nitrate which being highly mobile, has tendency to move to the periphery of the water front and remain unavailable to the tree (Haynes, 1985) [39]. Urea and nitrate are more evenly distributed down the soil profile below the emitter and had moved laterally in the profile to 15 cm radius from the emitter through fertigation (Haynes, 1990) [40]. Nitrate uptake rate of peach tree is low and hence, nitrate leaching risk is more in conventional method as the large amount of nitrogenous fertilizer are given to the tree (Gojon *et al*., 1991) [32]. Raina *et al.* (2005) [72] conducted an experiment and found higher NO_3^-N in the upper soil layers than conventional soil fertilization suggesting higher leaching losses in the later. The NO_4^-N concentration was higher under the emitters and decreased both vertically and laterally, whereas, NO_3^-N content decreased vertically and increased laterally up to 30 cm distance from the emitter. Because, under fertigation frequent applications of less volume of water produced a lower hydraulic gradient which did not allow the penetration of wetting front to the deeper soil layers, hence, minimized leaching losses (Bar-Yosef, 1999) [8]. The nitrogen availability steadily increased with increased depth up to 30 cm after that declined in all the distances at fertigation with 75 per cent recommended dose of nitrogen. Highest available P and K in soil were confined to 0-15 cm of soil layer under all fertigation levels and decreased with increase in distance from the emitters and soil depth (Singh *et al*., 2015) [88].

Phosphorus

Phosphorus (P) is the second most important nutrient after nitrogen in crop production, which under fertigation, seems to be modern technique where nutrients through water are supplied to crop roots continuously and results in higher water and fertilizer use efficiency by reducing nutrient losses through leaching and fixation in the soil to less available forms (Rauschkolb *et al*., 1976 and Zafar *et al*., 2013) [74, 104]. Comparatively better movement of P was found under fertigation than its soil application (Neilsen *et al*., 2010) [66]. The lateral distribution of available P under different fertigation levels was also noted to be decreased consistently with decreasing fertilizer rate. Phosphorus fertilization under drip irrigation facilitate both horizontal and vertical movement of native soil phosphorus near the outlet (Bacon and Davey, 1982) [5]. However, the distance of phosphorus movement directly correlated with application rate. In comparison to potassium, it is readily fixed in many soils (Kafkafi and Bar-Yosef, 1980) [48].

Potassium

Potassium (K) is an essential tree nutrient; mainly functions in pH stabilization, osmoregulation, enzyme activation and membrane transport processes and plays a very important role in tree growth, development and quality improvement. Its uptake is highly selective and transport is extremely mobile (Hagin *et al*., 2003) [37]. When potassium fertilizers are added to water, no adverse chemical reactions are observed. However, with mixture of different fertilizers, solubility reduces along with fertilizer incompatibility, for example calcium nitrate and potassium sulphate yield insoluble calcium sulphate. As several forms of K (potassium sulphate, potassium chloride and potassium nitrate) are readily soluble in water, ions move freely into the soil and are exchanged on the clay complex so that not readily leached away from soil (Bussi *et al*., 1991) [17]. Use of fertigation compared with localized soil application of potassic fertilizer can accelerate plant K availability (Guennelon and Cabibel, 1981) [35]. Many workers have detected considerable lateral and downward movement of trickle applied potassium (Goode *et al.*, 1978: Keng *et al.*, 1979; Kafkafi and Bar-Yosef, 1980) [34, 49, 48]. Inspite of less mobility than nitrate, potassium is more uniformly distributed in the wetted volume due to interaction with binding sites (Uriu *et al.*, 1977) [100]. Like ammonium, the K ion is adsorbed on the cation exchange sites on soil colloids so that the extent of movement is dependent upon the cation exchange capacity of the soil and the rate at which K is applied.

Various aspects of NPK fertigation in stone fruits

Growth responses of the tree under NPK fertigation

Growth responses as expressed in terms of trunk diameter, tree height and spread, annual shoot growth, leaf area, fresh and dry weight of leaves and weight of pruning wood have been studied through different experiments by scientists to explore the effects of fertigation. Southwick *et al*. (1999) [95] found that 0.11 to 0.23 kg actual N per tree is a sufficient amount of nitrogen to be given to the tree for increasing trunk cross sectional area and mass of pruned shoots with minimization of nitrate leaching into ground. Salgado *et al.* (2012) [77] found the effect of fertilization treatments through fertigation from his studies on both vegetative and reproductive parameters of young cherry trees cv. Brooks grafted onto 'MaxMa 14' rootstocks that there should be two way for the fertilization in cherry either fertilization should start after harvesting or a few weeks prior to expected date with nitrogen (>100 to <200 kg per hactare).

Fertigation with higher recommended dose significantly improved the growth parameters *viz.,* tree height, trunk girth, tree spread, canopy volume, annual shoot, leaf area and leaf chlorophyll as compared to the conventional soil fertilization in apricot, peach and nectarines (Raina *et al.*, 2005; Banyal *et al*., 2014 and Singh *et al*., 2015, respectively) [72, 6, 88]. Similarly, fertilizers applied through fertigation and drip irrigation lead to maximum growth in peach, plum and sweet cherry as compared to basin application (Layne *et al*., 1996; Verma *et al*., 2017; Rubauskis *et al*., 2003 and Ahmad *et al.*, 2010) [53, 101, 76, 1].

The increased growth parameters under fertigation in comparison to conventional application, might be attributed to frequent application of water and nutrient during the critical growth stages of trees which in turn ascribed to increase the nutrient use efficiency by minimizing leaching losses (Bar-Yosef, 1999) [8]. The existence of two or more nutrient ions in soil solution produce synergetic and antagonistic effects. Hence, uptake of N under fertigation simultaneously stimulates uptake of P and K which thereby, enhance the biomass of the trees.

Fruit physical parameters and yield components under NPK fertigation

The fruit physical parameters, *viz*. weight, length, volume, firmness, pulp content and yield attributing characters are prime indicators in economics of the experiment. Application of fertilizers significantly affects the physical parameters including yield. Nitrogen fertigation increased yield and average fruit weight of peach fruits (Bussi *et al*., 1994) [18]. Layne *et al*. (1996) [53] found linear increase in total yield of high density peach orchard. Callan and Westcott (1996) [20] observed the significant results on yield of tart cherry trees grown under drip irrigation and supplied with non-chloride potassium sources. Southwick *et al*. (1999) [95] observed that 0.11 and 0.23 kg nitrogen per tree is sufficient dose of nitrogen for optimum dry yield. Similarly, surface and subsurface drip fertigation improved fruit size and marketable yields (9-22 per cent) of peach tree over furrow or micro spray irrigation methods (Bryla *et al*., 2003&2005) [15,14].

NPK fertilization is responsible for highest yield and fruit length, however, phosphorus fertilization results in improved fruit diameter (Bybordi, 2013) [19]. Fertigation with full dose of recommended dose of fertilizers resulted in significant increase in physical parameters including fruit yield, fruit weight, fruit length and fruit diameter when compared with direct fertilizer application in cherry, peach, plum and nectarine (Ahmad *et al*., 2010; Banyal *et al.*, 2014; Verma *et al*., 2017; Rubauskis *et al*., 2003 and Singh *et al*., 2015) [1, 6, 101, 76, 88]. Injection fertilization with total amount of fertilizer resulted in higher fruit weight (individual fruit), which increased weight by 12.24 per cent over radial ditch fertilization with total amount of fertilizer treatment in 10 year old Abubai peach (Hong *et al*., 2017) [42]. In contrast, Neilsen *et al*. (2004, 2007) [64, 65] conducted an experiment using Lapins' sweet cherry to check the effect of different fertigation treatments. They found the fruit size to be smaller when crop load was at a maximum at fourth year with high nitrogen application and optimum yield with the medium nitrogen treatment. Similarly, Salgado *et al*. (2012) [77] found no significant difference in fruit yield of young cherry cv. 'Brooks' grafted onto 'MaxMa 14' with differences in fruit size and small number of fruits/ tree under different fertilizer treatments. Koumanov *et al*. (2016) [50] studied the effect of continuous and interrupted fertilizer application (both drip and sprinkler irrigation) through fertigation on fruit yield and yield attributing components of 'Burlat'/Mazzard and 'Lapins'/ 'Gisela5' of cherry. The variant shows no significant differences, with and without interruption of the nitrogen supply before fruit harvesting and hence, nitrogen fertigation, may be applied continuously without negative effects on the cherry fruit yield.

Fertigation in comparison to conventional fertilization results in improved water and nutrient management, facilitating positive effects on several aspects of fruit physical and yield attributes. The uniform distribution of NPK coupled with its confinement in active root zone increases the uptake of nutrients that might be responsible for synthesis of more metabolites, their translocation and in turn increased size, weight and volume of fruits characters (Bussi *et al.*, 1994 and Neilsen *et al*., 2007) [18, 65]. Frequency in nutrient uptake is possible through two mechanisms; continuous replenishment of nutrients in the depletion zone at the vicinity of root interface and enhanced transport of dissolved nutrients by mass flow, due to the higher averaged water content in the medium.

Fruit quality traits under NPK fertigation

There are many studies which have shown adverse effects of environmental factors (temperature, light, pH and organic matter of soil, pollution, pests, water and nutrient) on quality characteristics of fruits (Evers, 1994; Mozafar, 1996; Obreza *et al*., 1996 and Battilani and Solimando, 2004) [28, 61, 67, 11]. In general, stone fruits are comparatively more sensitive to irregular or changed water and nutrient condition and hence, fertigation techniques do better in case of these fruits. Various attributes which governs the quality of stone fruits includes; total soluble solids, acidity, sugar, ascorbic acid, anthocyanin and carotenoids *etc*. which are significantly affected by NPK fertigation in stone fruits. Fajt and Veberic (2002) [29] studied different fertilization methods and amounts of nutrients on peach fruits and found significantly effects on quality attributes; as the fruit matures, sucrose tends to increase, whereas, glucose and fructose decrease, there is also an increase in total soluble solids and malic acid content during fruit maturation, while shikimic acid showed a reduction in content.

Fertigation significantly affects fruit quality attributes in terms of total soluble solids, acidity and total sugars content in cherry, nectarine and peach (Ahmad *et al.*, 2010; Singh *et al*., 2015 and Verma *et al*., 2017) [1, 88, 101]. Additionally, Hong *et al*. (2017) [42] carried out an experiment on ten year old 'Abubai' peach and observed that injection fertilization with total amount of fertilizer treatment showed significantly higher soluble solid contents of single fruit compared with the radial ditch fertilizing with total amount of fertilizer treatment. However, Bussi *et al*. (1994) [18] carried out an experiment in peach orchards with different systems of fertilizers supplying as compared to ground applications of the same quantity of fertilizer and found that nitrogen fertigation in the form of NH_4NO_3 results in decreased total soluble solids of the fruits. Further, nitrogen fertigation has also shown non-significant effects on quality attributes of peach and cherry (Banyal *et al.*, 2014 and Koumanov *et al*., 2016) [6, 50].

Fertilizer application through fertigation improves water and nutrient availability in soil therefore, it is readily available to trees and facilitates positive effects on several aspects of fruit quality. The production of more photosynthates due to more number of leaves and leaf area besides enhanced physiological traits might have resulted in better transfer to the sink, the developing fruit, also, the involvement of potassium in carbohydrate synthesis, breakdown and translocation of starch, protein synthesis and neutralization of physiologically important organic acids, ultimately results in better quality traits. However, non-significant effects of fertigation recorded under various studies might be attributed to over fertilization of nitrogen to the tree (Albornoz, 2016) [2].

Nutrient status of tree under NPK fertigation

Leaf nutrient analysis is a common practice to provide a snapshot of nutrient status of tree at specific stages of tree growth. The nutrient concentration in leaves reflects the uptake of nutrients by the tree accurately. There are various studies suggesting the importance of leaf tissue indexing and fertigation responses in various stone fruit crops. Layne *et al*. (1996) [53] observed adequate to slightly excess range of most major elements in peach leaves cv. Harrow Beauty/Bailey during July-September. However, large and significant year effects was found on leaf nutrient concentrations using fertilizer with irrigation.

Fertilization with urea under drip irrigation at specific timing plays significant role to improve leaf nutrient status of French prune tree (Southwick *et al*., 1999) [95]. Neilsen *et al*. (2004) [64] studied the effect of sprinkler-fertigation with N fertilizer on Lapins sweet cherry trees and found that leaf and fruit N increased linearly from low (42 mg per liter) to high (168 mg per liter) values of N fertilizer, whereas, sprinkler fertigation of phosphorus and potassium did not show increment in either leaf or in fruit nutrient concentration. Krige and Stassen (2008) [51] conducted an experiment on nectarine and revealed that nitrogen was most abundant in the roots during dormancy, but the leaves contained the most nitrogen at pit hardening and harvesting stage while the phosphorus levels in roots found highest throughout the experiment. The highest percentage of potassium was in the permanent structures above the ground during dormancy, in the leaves during pit-hardening and in the fruit at harvest. Ahmad *et al*. (2010) [1] studied the effect of NPK through drip irrigation on sweet cherry and found that these are responsible for increasing nitrogen, phosphorus and potassium contents in leaves. Raina *et al.* (2011) [71] and Singh *et al.* (2015) [88] reported significantly higher leaf nitrogen content with drip fertigation and different levels of nitrogen fertigation as compared to soil fertilization either under irrigated or rainfed conditions. On contrary, Michael *et al.* (1979) [58] documented no influence of fertigation on leaf nitrogen concentration of peach and plum trees as compared to conventional method of fertilization.

The uptake of nutrient is affected by many factors in orchard and consequently every year nutrient status fluctuates slightly depending upon the season. However, for obtaining optimum yield, adequate nutrients level must be balanced in between soil and plant. The degree of variation of nutrient levels depends upon the ability of the tree to recycle or remobilize nutrients during the annual growth cycle. The higher leaf nutrient contents under drip fertigation may be attributed to the higher fertilizer use efficiency owing to its application in small amounts directly in the root zone coupled with less downward movement (Dong *et al.*, 2005 and Raina *et al.*, 2011) [25, 71].

Water and fertilizer use efficiency under NPK fertigation

Water and fertilizers are the two basic inputs in horticulture but their use efficiency is found to be low. Observation on these two inputs are one of the main objective in any fertigation experiment as it is very necessary for experiment economics. Several workers in recent past have found tangible results on water and fertilizer use efficiency in stone fruits. Bussi *et al.* (1994) [18] carried out an experiment in peach orchard with different systems of fertilizers supplying compared with ground application and revealed that the amounts of fertilizers injected through trickle irrigation should be modulated each year according to the expected productive capacity of the orchard as to improve the fertilizer use efficiency. Papadopoulos (1997) [68] reported that under fertigation, nutrient use efficiency can be increased by reduced fluctuations in salinity of soil solution due to application of fertilizers through fertigation, which improves soil solution conditions particularly in saline conditions. Hasan *et al.* (2004) [38] found that the fully automated fertigation system resulted in saving of water up to 40 per cent and fertilizer up to 30 per cent. Apparently, Raina *et al.* (2005) [72] conducted an experiment to investigate the effect of fertigation on fertilizer use efficiency of apricot with different levels of nitrogen (100, 80, 60 and 40 per cent of recommended dose) through drip fertigation compared with conventional methods and suggested that 40 per cent savings of nitrogenous fertilizer was found with drip fertigation. Similarly, Ahmad *et al.* (2010) [1] conducted an experiment on sweet cherry and found that as compared to full dose of NPK applied directly in the field, 1/3rd recommended dose of NPK applied through drip irrigation increases fertilizer use efficiency of the tree. Further, Hong *et al.* (2017) [42] carried out an experiment on ten year old Abubai peach grown under the field condition and found that water and fertilizer use efficiency significantly improved with injection fertilizing system. Verma *et al.* (2017) [101] conducted an experiment to study comparative performance of fertigation and conventional soil fertilization on five year old peach and observed that the maximum fertilizer use efficiency was achieved in 80 per cent of recommended dose of NPK through drip + drip irrigation at 100% crop evapotranspiration treatment combination.

Water and nutrient use efficiency are major concern for sustainable horticultural production which is appreciably increased under drip fertigation (Alva, 2005 and Shirgure and Srivastava, 2014) [3, 84]. The improved results in relation to water and fertilizer use efficiency in stone fruits might be attributed to efficient utilization of water and nutrient during critical period of trees. However, Neilsen and Neilsen (2005) [63] found that under orchard conditions, many factors (time of application, quality and quantity) determine whether distribution of fertilizers and water given to the growing tree is sufficient or not, because source of these inputs may be natural or artificial.

Table 1: Brief summary of work done on effects of NPK fertigation in stone fruits.

Characters	Fruits	Fertigation treatments	Conclusive findings	References
Growth	Apricot	N + P + K	Higher annual shoot growth, tree height and canopy volume with 100% RD	Raina *et al.* (2005) [72]
	Cherry	N + P + K	Vigorous growth with fertigation as compared to other means of fertilization	Neilsen *et al.* (2007) [65]
		N + P + K	Higher vegetative growth when fertigation applied after harvest or few weeks earlier to harvest and lower number of fruit nodes with 200 kg N per hactare	Salgado *et al.* (2012) [77]
	Nectarine	N + K	Non-significant effects on vegetative growth	Battilani, 1997 [9]
		N + P + K	Increased vegetative growth attributes	Singh *et al.* (2015) [88]
	Peach	N	Higher trunk circumference and weight of pruning wood	Bussi *et al.* (1994) [18]
		N + K	Larger TCSA with high frequency drip fertigation	Layne *et al.* (1996) [53]
		N	Higher shoot extension growth and tree spread with $^2/_3$ and full RD and non-significant effect on stem girth	Banyal *et al.* (2014) [6]
		N + P + K	Increased tree height, tree spread, trunk girth and annual shoot growth with 100% RD	Verma *et al.* (2017) [101]
	Plum	N	Larger TCSA	Southwick *et al.* (1999) [95]
		N + P + K	Higher trunk circumference initially thereafter decreased with increased tree yield	Rubauskis *et al.* (2003) [76]
Fruit physical and Yield	Apricot	N + P + K	Higher yield with 80% RD and non-significant effects on fruit weight and firmness	Raina *et al.* (2005) [72]
		N + P + K	Higher fruit weight and yield with 100% RD	Raina *et al.* (2011) [71]
		N + P + K	Increased fruit yield and higher leaf area	Bybordi (2013) [19]
	Cherry	N	Increased yield and good fruit size	Neilsen *et al.* (2004) [64]
		N + P + K	More yield with fertigation as compared to other means of	Neilsen *et al.* (2007) [65]

			fertilization	
		N + P + K	More yield with fertigation as compared to other means of fertilization	Ahmad *et al*. (2010) [1]
		N + P + K	Optimum fruit size and firmness with both continuous and interrupted fertigation	Koumanov *et al*. (2016) [50]
	Nectarine	N + K	Good yield and fruit weight in fertigation, however, non-significant effects on number of fruit per tree	Battilani, 1997 [9]
		N + P + K	Higher fruit weight, length and breadth with 75% RD	Singh *et al*. (2015) [88]
	Peach	N	Higher fruit weight and yield	Bussi *et al*. (1994) [18]
		N + K	Non-significant effect on yield	Layne *et al*. (1996) [53]
		N + P + K	Non-significant effects on fruit weight and size	Fajt and Veberic (2002) [29]
		N	Higher fruit yield, weight, length and diameter with $^{2}/_{3}$ and full RD	Banyal *et al*. (2014) [6]
		N + P + K	Higher fruit weight and yield	Hong *et al*. (2017) [42]
		N + P + K	Higher yield, fruit weight, length and volume with 100% RD	Verma *et al*. (2017) [101]
	Plum	N	Higher dry yield and number of dry fruits	Southwick *et al*. (1999) [95]
		N + P + K	Good yield in fertigation	Rubauskis *et al*. (2003) [76]
Quality	Apricot	N + P + K	Non-significant effects on TSS, acidity and total sugar	Raina *et al*. (2005) [72]
		N + P + K	Higher fruit TSS	Bybordi (2013) [19]
	Cherry	N + P + K	Elevated fruit TSS	Neilsen *et al*. (2007) [65]
		N + P + K	Higher TSS and non-significant effect on acidity	Ahmad *et al*. (2010) [1]
		N + P + K	Optimum sugar, acidity and ascorbic acid contents both under continuous and interrupted fertigation	Koumanov *et al*. (2016) [50]
	Nectarine	N + P + K	More TSS with 100% RD, whereas, more acidity and sugars with 75% RD	Singh *et al*. (2015) [88]
	Peach	N	Decreased TSS	Bussi *et al*. (1994) [18]
		N + P + K	Non-significant effects on TSS, sugar and organic acid under fertigation	Fajt and Veberic (2002) [29]
		N	Non-significant effect on TSS	Banyal *et al*. (2014) [6]
		N + P + K	Higher TSS	Hong *et al*. (2017) [42]
		N + P + K	Higher TSS, total and reducing sugars and lower acidity with 100% RD	Verma *et al*. (2017) [101]
Nutrient Status	Apricot	N + P + K	Higher leaf N, P and K with 100% RD	Raina *et al*. (2011) [71]
	Cherry	N	Higher leaf and fruit N with sprinkler fertigation, whereas, non-significant effects on P and K contents	Neilsen *et al*. (2004) [64]
		N + P + K	Higher leaf N with $^{2}/_{3}$ RD, whereas, higher P and K with full RD	Ahmad *et al*. (2010) [1]
	Nectarine	N + P + K	More leaf N, P and K with 100% RD	Singh *et al*. (2015) [88]
	Peach	N + K	Higher leaf N, whereas, non-significant effect on K content	Layne *et al*. (1996) [53]
	Plum	N	Higher leaf N through fertigation than control	Southwick *et al*. (1999) [95]
Water and Fertilizer use efficiency	Apricot	N + P + K	Higher fertilizer use efficiency	Raina *et al*. (2005) [72]
		N + P + K	Higher water and fertilizer use efficiency	Bybordi (2013) [19]
	Cherry	N + P + K	Higher fertilizer use efficiency	Ahmad *et al*. (2010) [1]
	Nectarine	N + P + K	Higher fertilizer use efficiency	Singh *et al*. (2015) [88]
	Peach	N + P + K	Higher water and fertilizer use efficiency	Hasan *et al*. (2004) [38]
		N	Higher fertilizer use efficiency with $^{1}/_{3}$ RD	Banyal *et al*. (2014) [6]
		N + P + K	Higher water and fertilizer use efficiency	Hong *et al*. (2017) [42]
		N + P + K	Higher fertilizer use efficiency with 80% RD	Verma *et al*. (2017) [101]

(**Abbreviations;** N= nitrogen, P= phosphorus, K= potassium, RD= recommended dose, TCSA= trunk cross sectional area, TSS= total soluble solids)

Conclusion

Stone fruit plantation have now attained a status worldwide and contributing significant account in economic development of any country by providing employments to many peoples in various aspects right from planting to harvesting and lowering the pressure on other major fruits. Fertigation in stone fruits have facilitated many advantages, however, there are some constraints in adopting the technology for sustainable production of these crops. The poor adoption can be attributed to number of factors such as huge initial investment, non-availability of water soluble fertilizer at reasonable price in remote or hilly areas. Lack of efficient and improved water and fertilizer management practices are some of the main issues contributing low production of stone fruits, the reason behind inefficient utilization of water and nutrient by the trees in conventional methods of application. Fertigation holds a great potential since it effects and improves the growth, yield and quality parameters of the stone fruits. Thus, stone fruit orchardists are encouraged to implement such a scientific and judicious water and fertilizer saving technology than conventional methods. Considering the limited potential of resources (water and fertilizers), it has become essential to adopt such technologies so as to avoid the demand and stress in the future. Therefore, fertigation practice becomes efficient tool for increasing the production and productivity of the stone fruits and proved beyond doubt about its utility to fruit cultivation.

References

1. Ahmad MF, Samanta A, Jabeen A. Response of sweet cherry (*Prunus avium*) to fertigation of nitrogen, phosphorus and potassium under kerawa land of Kashmir valley. Indian Journal of Agricultural Sciences. 2010; 80(6):512-516.
2. Albornoz F. Crop responses to nitrogen over fertilization: A review. Scientia Horticulturae. 2016; 205:79-83.
3. Alva AK. Role of fertigation in horticultural crops: Citrus. Fertigation proceedings: selected papers presented at the joint. 2005; 20:61-75.
4. Ashraf N, Sharma MK, Bhat MY. Micro irrigation and fertigation in fruit trees: A review. Environment and Ecology. 2012; 12(3):1252-1257.
5. Bacon PE, Davey BG. Nutrient availability under trickle irrigation: II. Mineral nitrogen. Soil Science Society of America Journal. 1982; 46:987-993.
6. Banyal SK, Sharma D, Jarial K. Effect of nitrogen fertigation on yield and fruit quality of peach (*Prunus persica* L.) under low hill conditions of Himachal Pradesh. Current Advances in Agricultural Sciences. 2014; 6(2):158-160.
7. Barber SA. Soil nutrient bioavailability. 2nd eds., John Wiley and Sons, New York, 1995.
8. Bar-Yosef B. Advances in fertigation. Advance in Agronomy. 1999; 65:1-79.
9. Battilani A. Effects of irrigation and fertigation on the yield and market quality of nectarines. Acta Horticulturae. 1997; 449(1):153-159.
10. Battilani A. Manipulating quality of horticultural crops with fertigation. Acta Horticulturae. 2008; 792:47-60.
11. Battilani A, Solimando D. Yield, quality and nitrogen use efficiency of fertigated watermelon. Acta Horticulturae. 2004; 700:85-90.
12. Brahmanand PS, Singandhupe RB. Drip irrigation in India: Current status and future needs. In: Proceedings of International Conference on Micro and Sprinkler Irrigation System, 2000, 44-51.
13. Bryan BB, Thomas EL. Distribution of fertilizer materials applied through sprinkler irrigation systems. University of arkansas agricultural experimental station, Fayetteville. 1958; 598:12.
14. Bryla DR, Dickson E, Shenk R, Johnson RS, Crisosto CH, Trout TJ. Influence of irrigation method and scheduling on patterns of soil and tree water status and its relation to yield and fruit quality in peach. Hort Science. 2005; 40:2118-2124.
15. Bryla DR, Trout TJ, Ayars JE. Growth and production of young peach trees irrigated by furrow, micro jet, surface drip or subsurface drip systems. Hort Science. 2003; 38(6):1112-1116.
16. Burt C, O'Connor K, Ruehr T. Fertigation. San luis obispo, CA: Irrigation training and research center, California polytechnic state university, California, USA, 1998.
17. Bussi C, Huguet JG, Defranc H. Fertilization scheduling in peach orchards under trickle irrigation. Journal of Horticulture Science. 1991; 66:487-493.
18. Bussi C, Huguet JG, Besset J, Girard T. Effects of nitrogen fertilization applied during trickle irrigation on the growth and fruit yield of peach. European Journal of Agronomy. 1994; 3(3):243-248.
19. Bybordi A. Quantitative and qualitative effects of nutrient applications and irrigation methods on apricot. Middle-East Journal of Scientific Research. 2013; 14(3):423-431.
20. Callan NW, Westcott MP. Drip irrigation for application of potassium to tart cherry. Journal of Plant Nutrition. 1996; 19(1):163-172.
21. Chen W, Zhenan H, Laosheng W, Yongchao L, Changzhou W. Evaluating salinity distribution in soil irrigated with saline water in arid regions of northwest China. Agricultural Water Management. 2010; 97:2001-2008.
22. Claassen N, Steingrobe B. Mechanistic simulation models for a better understanding of nutrient uptake from soil. In: Mineral nutrition of crops, fundamental mechanisms and implications, ed. Rengel Z. Haworth Press, New York, 1999, 327-367.
23. Clark GA, Stanley CD, Maynard DN, Hochmuth GJ, Hanlon EA, Haman DZ. Water and fertilizer management of micro-irrigated fresh market tomatoes. American Society of Agricultural and Biological Engineers. 1991; 34:429-435.
24. Dinnes DL, Karlen DL, Jaynes DB, Kaspar TK, Hatfield JL, Colvin TS *et al*. Nitrogen management strategies to reduce nitrate leaching in tile-drained midwestern soils. Agronomy Journal. 2002; 94:153-171.
25. Dong S, Cheng L, Scagel CF, Fuchigami LH. Timing of urea application affects leaf and root N uptake in young Fuji/M9 apple trees. The Journal of Horticultural Science and Biotechnology. 2005; 80:116-120.
26. Edwards HH, Bruce RR, Horton BD, Chesness JL, Wehunt EJ. Soil cation and water distribution as affected by NH_4NO_3 applied through a drip irrigation system. Journal of American Society for Horticultural Science. 1982; 197:1142-1148.
27. Elfving DC. Crop response to trickle irrigation. Horticulture Review. 1975; 6:1-36.
28. Evers AM. The influence of fertilization and environment on some nutritionally important quality criteria in vegetables: A review of research in the nordic countries. Agricultural Science in Finland. 1994; 3:177-187.
29. Fajt N, Veberic R. The influence of fertirrigation on the development of fruits and the contents of sugars and organic acids in 'Redhaven' peach. Acta Horticulturae. 2002; 592:323-329.
30. Fares A, Abbas F. Irrigation systems and nutrient sources for fertigation. Soil and Crop Management. 2009; 25:1-4.
31. Gastoud B, Grisolle JP, Niel P. Possibilites et mise en oeuvre de irrigation fertilisante. Irrigazion e Drenaggio. 1982; 1:3-11.
32. Gojon A, Bussi C, Grignon C, Salsac L. Distribution of NO_3 reduction between roots and shoots of peach-tree seedlings as affected by NO_3 uptake rate. Physiologia Plantarum 1991; 82:505-512.
33. Goldberg D, Shmueli M. Drip irrigation a method used under arid and desert conditions of high water and soil salinity. American Society of Agricultural Engineers. 1970; 13:38-41.
34. Goode JE, Higgs KH, Hyrycz KJ. Trickle irrigation and fertilization of tomatoes in highly calcareous soils. Journal of Horticultural Science. 1978; 53:307-316.
35. Guennelon R, Cabibel B. Influence del' activite du systeme racinaire de pommiers sur la repartition des solutes en irrigation localise'e. Agronomie. 1981; 1:323-330.

36. Hagin J, Lowengart A. Fertigation for minimizing environmental pollution by fertilizers. Fertilizer Research. 1996; 43(1):5-7.
37. Hagin J, Sneh M, Lowengart A. Fertigation: Fertilization through irrigation. International potash institute, Schneidergasse, 27, P.O. Box 1609, CH-4001 Basel I Switzerland, 2003.
38. Hasan M, Sirohi NPS, Kumar V, Sharma MK, Singh AK. Performance evaluation of different irrigation scheduling methods for peach through efficient fertigation system network. Acta Horticulturae. 2004; 662:193-197.
39. Haynes RJ. Principles of fertilizer use for trickle irrigated crops. Fertilizer Research. 1985; 6:235-255.
40. Haynes RJ. Movement and transformations of fertigated nitrogen below trickle emitters and their effects on pH in the wetted soil volume. Fertilizer Research. 1990; 23:105-112.
41. Haynes RJ, Swift RS. Effect of trickle fertigation with three forms of nitrogen on soil pH, levels of extractable nutrients below the emitter and plant growth. Plant and soil. 1987; 102:211-221.
42. Hong B, Pei S, Donghua GUO, Hengbo Q, Chonghui F, Hangkong L *et al*. Effects of injection fertilizing on soil environment, fruit yield and fruit quality of peach orchard. Acta Botanica Boreali-Occidentalia Sinica, 2017, 3.
43. Huguet C. Evolution des concepts de la nutrition des arbres fruitiers. Cahiers de Researchers I.N.R.A., Montfavet, 1980.
44. Imamsaheb SJ, Patil MG, Harish DK. Effect of different levels of fertigation on productivity and nutrients uptake in processing tomato (*Solanum lycopersicum*) genotypes. Agricultural Science Research Journal. 2011; 2:217-220.
45. Jacob D. Peach. In: Temperate horticulture current scenario. Oxford Book Company, New Delhi, India, 2010, 73-88.
46. Jungk AO. Dynamics of nutrient movement at the soil-root interface. In: Plant Roots - the Hidden Half, eds. Waisel Y, Eshel A, Kafkafi U. Marcel Dekker, Inc., New York, 1996, 529-556.
47. Kabirigi M, Shrestha OP, Prescella BV, Niamwiza C, Quintin SP, Mwamjengwa IA *et al*. Fertigation for environmentally friendly fertilizers application: constraints and opportunities for its application in developing countries. Agricultural Sciences. 2017; 8:292-301.
48. Kafkafi U, Bar-Yosef B. Trickle irrigation and fertilization of tomatoes in high calcareous soils. Agronomy Journal. 1980; 72:893-897.
49. Keng JCW, Scott TW, Lugo-Lopez MA. Fertilizer management with drip irrigation in an oxisol. Agronomy Journal. 1979; 71:971-980.
50. Koumanov KS, Staneva IN, Kornov GD, Germanova DR. Sweet cherry fruit quality under fertigation. Acta Horticulturae. 2016; 1139:551-558.
51. Krige GT, Stassen PJC. Mineral nutrient distribution and requirement of pulse drip fertigated 'Donnarine' nectarine trees. Acta Horticulturae. 2008; 772:355-360.
52. Kumar A. Pressurized irrigation system towards enhanced water use efficiency. Souvenir XXXIVth annual convention. Indian Society of Agricultural Engineers 1999, 26-44.
53. Layne REC, Tan CS, Hunter DM. Irrigation and fertilizer application methods affect performance of high density peach orchards. Hort Science. 1996; 31(3):370-375.
54. Li DG, Xu XC, Zhang YL. Fertigation and fertilizer. Journal of Zhengzhou University of Technology. 2002, 1:21.
55. Magen H. Fertigation: An overview of some practical aspects. Fertilizer News. 1995; 40:97-100.
56. Malhotra SK. Water soluble fertilizers in horticultural crops: An appraisal. Indian Journal of Agricultural Sciences. 2016; 86(10):1245-56.
57. Manohar K, Khan R, Kariyanna MM, Sreerama R. An overview of status, potential and research accomplishment of drip irrigation in Karnataka. In: Proceedings of International Conference on Micro and Sprinkler Irrigation System. 2001, 69-79.
58. Michael WS, Kenworthy AL, Bedford CL. The response of fruit trees to injection of nitrogen through a trickle irrigation system. Journal of American Society for Horticultural Science. 1979; 104:311-313.
59. Mishra KK, Pyasi SK. Moisture distribution pattern in drip irrigation. Journal Research of Birsa Agricultural University, Ranchi. 1993; 5:59-64.
60. Mmolawa K, Or D. Root zone solute dynamics under drip irrigation: A review. Plant and Soil. 2000; 222:163-190.
61. Mozafar A. Decreasing the NO_3 and increasing the vitamin C contents in spinach by a nitrogen deprivation method. Plant Foods for Human Nutrition. 1996; 49:155-162.
62. Nanda RS. Fertigation to enhance farm productivity. Indian Journal of Fertilizers. 2010; 6(2):13-22.
63. Neilsen D, Neilsen G. Fertigation of deciduous fruit trees: Apple and sweet cherry. Fertigation proceedings: Selected papers presented at the joint. 2005; 20:76-88.
64. Neilsen G, Kappel F, Neilsen D. Fertigation method affects performance of 'Lapins' sweet cherry on Gisela 5 rootstock. Hort Science. 2004; 39(7):1716-1721.
65. Neilsen G, Kappel F, Neilsen D. Fertigation and crop load affect yield, nutrition and fruit quality of 'Lapins' sweet cherry on Gisela 5 rootstock. Hort Science. 2007; 42(6):1456-1462.
66. Neilsen GH, Neilsen D, Kappel F, Toivonen P, Herbert L. Factors affecting establishment of sweet cherry on Gisela 6 rootstock. Hort Science. 2010; 45(6):939-945.
67. Obreza TA, Pitt DJ, McGovern RJ, Spreen TH. Deficit irrigation of micro irrigated tomato affects yield, fruit quality and disease severity. Journal of Production Agriculture. 1996; 9:270-275.
68. Papadopoulos I. Fertilizers in irrigated agriculture and potential pollution impact. In: Proceedings of the international conference on Water management, salinity and pollution control towards sustainable irrigation in the Mediterranean region, Bari, Italy: CIHEAM, 1997, 193-215.
69. Patten K, Nimr G, Neuendorff E. Fertilization method and liming rate effects on peach tree growth and soil pH. Acta Horticulturae. 1989; 254:323-327.
70. Raina JN. Drip irrigation and fertigation: Prospects and retrospect's in temperate fruit production: In: Enhancement of temperate fruit production in changing climate, eds. Jindal KK, Gautam DR. UHF, Solan, India, 2002, 105-113.
71. Raina JN, Sharma T, Suman S. Effect of drip fertigation with different fertilizers on nutrient distribution in soil, leaf nutrient content and yield of apricot (*Prunus armeniaca* L.). Journal of the Indian Society of Soil Science. 2011; 59(3):268-277.

72. Raina JN, Thakur BC, Suman S, Sephia RS. Effect of fertigation through drip system on nitrogen dynamics, growth, yield and quality of apricot. Acta Horticulturae 2005; 696:198-201.
73. Rajput TBS, Patel N. Water soluble fertilizers: Opportunities and challenges. FAI, Annual seminar, 2002, SII-3/1-9.
74. Rauschkolb RS, Rolston DE, Miller RJ, Carlton AB, Burau RG. Phosphorus fertilization with drip Irrigation. Soil Science Society of America Journal. 1976; 40:68-72.
75. Rolston DE, Rauschkolb RS, Phene CJ, Miller RJ, Uriu K, Carlson RM *et al*. Applying nutrients and other chemicals to trickle irrigated crops, Bulletin No. 1893, University of California, 1979.
76. Rubauskis E, Skrivele M, Dimza I. Growth and yielding of plum trees in experiment with fertigation and rootstocks. Proceedings in Agronomy, agris.fao.org, 2003.
77. Salgado E, Livellara N, Pinilla J. Programmed fertigation effects on the growth and production of young cherry trees in central Chile. Journal of Soil Science and Plant Nutrition. 2012; 12(1):15-22.
78. Sandal SK, Kapoor R. Fertigation technology for enhancing nutrient use and crop productivity: An overview. Himachal Journal of Agricultural Research. 2015; 41(2):114-121.
79. Sathya S, Pitchai GJ, Indirani R, Kannathasan M. Effect of fertigation on availability of nutrients (N, P & K) in soil: A review. Agriculture Review. 2008; 29(3):214-219.
80. Sharma R, Bhardwaj S, Choudhary M. Fertigation on fruit crops: A review. Annals of Biology. 2014; 30(1):48-53.
81. Sharpe RH, Sherman WB, Martsolf JD. Peach cultivars in Florida and their chilling requirements. Acta Horticulturae. 1990; 279:191-197.
82. Shirgure PS. Micro-irrigation systems, automation and fertigation in citrus. Scientific Journal of Review. 2012; 1:156-69.
83. Shirgure PS. Citrus fertigation: A technology of water and fertilizers saving. Scientific Journal of Crop Science. 2013; 2(5):56-66.
84. Shirgure PS, Srivastava AK. Fertigation in perennial fruit crops: Major concerns. Agrotechnology. 2014; 3(1):1-2.
85. Silber A, Xu G, Levkovitch I, Soriano S, Bilu A, Wallach R. High fertigation frequency: The effects on uptake of nutrients, water and plant growth. Plant and Soil. 2003; 253:467-477.
86. Singh D, Kumari N. Fertigation in fruit crops. International Journal of Economic Plants. 2017; 4(3):125-130.
87. Singh D, Singh R. Nitrogen nutrition of peach: A review. Agricultural Review. 2002; 23(1):46-52.
88. Singh D, Sharma SD, Kumar P. Nitrogen fertigation for nectarines (*Prunus persica* var. *nucipersica*): Lateral and vertical nutrient acquisition and cropping behaviour in rainfed agro-ecosystem. Indian Journal of Agricultural Sciences. 2015; 85(11):1440-1447.
89. Singh Y, Singh CS, Singh A, Singh AK, Singh K. Fertigation: A key for hi-tech. agriculture. Agriculture Water Management. 2005; 52:128-149.
90. Sivanappan RK. Prospects of micro-irrigation in India. Irrigation and Drainage Systems. 1994; 8(1):49-58.
91. Smith MW, Kenworthy AL, Bedford CL. The response of fruit trees to injections of nitrogen through a trickle irrigation system. Journal of American Society for Horticultural Science. 1979; 104:311-313.
92. Smith S. Agricultural irrigation-fertigation facts. The fundamentals of applying fertilizer through an irrigation system. Online Edition: IBT, 2001. http:// www.irrigation.org/ibt/0103/p33.htm
93. Sneh M. The history of fertigation in Israel. International Water & Irrigation Review 1995; 15:17-20.
94. Solaimalai A, Baskar M, Sadasakthf A, Subburamu K. Fertigation in high value crops: A review. Agriculture Reviews. 2005; 26:1-13.
95. Southwick SM, Rupert ME, Yeager JT, Ampinen BD, Dejong TM, Weis KG. Effects of nitrogen fertigation on fruit yield and quality of young `French' prune trees. Journal of Horticultural Science & Biotechnology. 1999; 74(2):187-195.
96. Srinivas K. Fertigation in horticultural crops. In: Crop improvement and production technology of horticultural crops, eds. Chadha KL, Ahloowalia, BS, Prasad KV, Singh SK. Proceedings of the First Indian Horticulture Congress, New Delhi, India. 2004; 1:506-525.
97. Srivastava AK, Malhotra SK. Nutrient use efficiency in perennial fruit crops: A review, Journal of Plant Nutrition, 2017. DOI: 10.1080/01904167.2016.1249798
98. Tagliavini M, Marangoni B. Major nutritional issues in deciduous fruit orchards of northern Italy. Hort Technology. 2000; 12:26-31.
99. Tromp J, Bolding PJ. L'irrigation fertilisante des vergers. Fruit beige. 1988; 423:221-227.
100. Uriu K, Carlson RM, Henderson DW. Application of potassium fertilizers to prunes through a drip irrigation system. Proceedings of VIIth International Agriculture Plastics Congress, San Diego, California, USA, 1977, 211-214.
101. Verma P, Chandel JS, Sharma NC, Thakur Y. Effect of fertigation on growth, yield, fruit quality and fertilizer use efficiency of peach. Journal of Hill Agriculture. 2017; 8(2):181-186.
102. Wu IP. Micro irrigation design for trees. American Society of Agricultural Engineers. 1993; 93:21-28.
103. Yarwood CE. Water and the infection process. In Water deficit and plant growth, ed. Kozlowski TT. Academic Press, New York, USA. 1978; 5:141-165.
104. Zafar I, Muhammad Y, Muhammad A, Riaz A. Phosphorus fertigation: A technique for enhancing P fertilizer efficiency and yield of wheat and maize. Soil Environment. 2013; 32(2):146-151.