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RESPONSE OF DRIP IRRIGATION, FERTIGATION AND MULCHING IN FRUIT CROPS FOR ENHANCED QUALITY ATTRIBUTES AND PRODUCTIVITY—A REVIEW

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ABSTRACT

Horticultural production in India is to be increased to improve the nutritional security and economy of the people. Production can be increased manifolds through the adoption of modern technologies like micro-irrigation, fertigation and mulching, which increases the water use efficiency (WUE) and fertilizer use efficiency (FUE). Drip irrigation is economically viable for most of horticultural crops viz., banana, grapes, citrus, pomegranate and apple. Drip irrigation is the most appropriate tool to supply water and nutrients to the plant, which not only saves water but also increases the production of fruit crops along with rereduction in labour. Although the fertilizers are costly entities, but their requirement is essential for proper growth and development of plants. These fertilizers through drip irrigation ensures proper utilization and results in better yield. Mulching along with drip and fertigation, controls weeds population and further increases the efficiency of the system. The shrinking land : man and water : man ratio, increasing fertilizer prices, haunting energy crisis, wide spread pollution and fast degradation of natural resource, further emphasize the need for improved water and fertilizer use efficiency. This paper review the drip irrigation and fertigation research conducted by different workers in the field of horticulture on different fruit crops viz., apple, apricot, banana, guava, grape, mango, litchi, pomegranate, papaya and citrus. Results from these studies indicated significant increase in yield, enhancement of water use efficiency and nutrient use efficiency in most of the fruit crops.

Key words : *Drip irrigation, fertigation, FUE, mulching, WUE and yield.*

Water and fertilizers are two essential inputs for augmenting crop production. The constant increase in population and decrease in irrigation water availability emphasis a more efficient use of these inputs. In India, irrigation alone contributes 60 per cent growth in the agricultural productivity (Singh and Sharma, 2013). The scarcity of water means less irrigation to crop plants and consequently lower yields. However, sometimes water is available in plenty. In that case, farmers generally carry out conventional i.e. flood and furrow methods of irrigation. These methods uses excess irrigation that reduces crop production, decreases the soil fertility, cause water logging and salinity. Besides, it results in 50 per cent loss of water due to evaporation, transpiration, deep-percolation and surface runoff. A study by International Water Management Institute has shown that about 50 per cent of increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation (Seckler *et al.,* 1998). Therefore, the selection and adoption of appropriate irrigation technology is more important for efficient and economic utilization of water so that optimum productivity is achieved, because both scarce and excess irrigation hamper crop production.

One such modern technology of irrigation is micro-irrigation which includes sprinkler and drip irrigation. Drip irrigation is economically viable for most of horticultural crops viz., apple, grapes, banana, citrus, pomegranate etc. Drip irrigation is an irrigation method that saves water by allowing water to drip slowly to the root zone of plants, through a network of valves, pipes, tubing and emitters. Drip irrigation is the most effective way to supply water and nutrients to the plant, which not only saves water but also increases yield in fruit crops. Drip irrigation results in lower water consumption (Fallahi *et al.,* 2007; Neilsen *et al.,* 2008, 2006) while producing higher quality fruits.

Application of fertilizers through an irrigation system by the use of drippers, provides an excellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency (FUE), reducing the fertilizer application dosages and increasing return on the fertilizer invested (Hagin *et al.,* 2002). For most of the fruit crops, the efficiency of fertilizer uptake with fertigation is improved from 10 to 35 per cent (Neilsen *et al.,* 2001; Mussaddak, 2007), because the nutrients dissolved in water can be quickly delivered to the root zone. Bravdo and Proebsting (1993) reported that the higher effectiveness of fertigation depends on the possibility of applying optimal concentrations of fertilizing solutions and a higher root density in the wetted soil volume.

Mulching along with drip irrigation and fertigation, controls weed population and further increases the efficiency of the system. Mulching is used to cover soil

surface around the plants to create congenial conditions for the plant growth. Weed control, temperature moderation, salinity reduction etc are the desirable effects of the mulching.

Horticultural crops play a pivotal role in India's economy by improving the income of the rural peoples. Cultivation of these crops is labour intensive and generate lot of employment opportunities for the rural populations. Fruits are also rich source of vitamins, minerals, proteins, carbohydrates etc. which are essential in human nutrition. Hence, these are referred to as protective foods and assumed great importance as nutritional security of the people. Thus, cultivation of horticultural crops plays a vital role in the prosperity of a nation and is directly linked with the health and happiness of the people. Horticultural production has made spectacular increase in recent years in India, but in spite of this progress the per capita availability of fruits and vegetables in India is only about 198.9 g/day/person, which is far below the minimum dietary requirement of 400 g/day/person (Anonymous, 2013). Several studies have been conducted all over the world to analyze the effect of drip irrigation, fertigation and mulching on different fruit crops. Here an attempt is made to summaries the available literature, giving emphasis to fruit production. The various aspects of drip, fertigation and mulching are brought under different heads.

Effect of drip irrigation on water saving and water use efficiency : The relatively higher water productivity under drip irrigation as compared to surface irrigation was due to the higher water uptake by crop as a result of direct application of small amount of water in several splits into root zone without wetting the entire area and higher water distribution efficiencies in the soil profile (Bangar and Chaudhary, 2004). Sharma *et al.,* 2005 reported that highest water-use efficiency (1.27 q/ha/cm) was recorded under the treatment of drip irrigation at 60 per cent of evapotranspiration and black polyethylene mulch, which was 269.9 per cent higher than the lowest water-use efficiency (0.36 q/ha/cm) recorded under the rainfed and control. The drip system, besides giving a saving of 59.1 per cent of irrigation water, resulted in 30.4 per cent higher fruit yield of peach as compared to surface irrigation (Verma *et al.,* 2007). Panigrahi *et al.* (2010) irrigation water use efficiencies of 60% water through drip with black polythene mulch was nearly 3.27 times the water use efficiencies of surface irrigation treatment. Maximum WUE (35.1 kg/ha/mm) was noted in the treatment which was irrigated with drip at 80 per cent ETc and lowest WUE (23.2 kg/ha/mm) was noted in the conventional irrigation system (Sharma *et al.,* 2012). Pawar and Dingre (2013) indicated the beneficial effects of drip irrigation in terms of 23 per cent increase in yield and 45.3 per cent water saving whereas drip with fertigation resulted into 24 to 46 per cent increase in banana yield with equal amount of water saving as compared to conventional method. Sharma *et al.* (2013) reported that drip irrigation at 100% ETc registered the highest water productivity of 15.4 kg/ ha/mm with water saving of 9.6 per cent as compared to surface irrigation which exhibited water productivity of 12.7 kg/ ha/mm. Pramanik *et al.* (2014) reported that drip irrigation, as a whole, registered the higher banana fruit yield and WUE with savings of 38.3 to 41.5 per cent of water compared to surface irrigation. Singh *et al.* (2015) reported that maximum water saving (47.52%) was recorded through drip irrigation as compared to control. Pramanik and Patra (2016) reported that drip irrigation at 60% CPE with fertigation at 80% RDF produced maximum growth, yield and fruit quality attributes and higher irrigation water use efficiency, besides water saving of 41.7 per cent for plant and 40.4 per cent for ratoon crop of banana over the surface irrigation and soil fertilization.

Effect of drip irrigation on yield attributes : Hedge and Srinivas (1990) reported that adoption of surface drip irrigation increased the banana fruit yield from 6 to 10 per cent over flood irrigation (78.98 t/ha). Agrawal and Agrawal (2005) reported that irrigation with drip irrigation in general increased the banana yield as compared to surface irrigation. Drip irrigation system was found better for higher growth and yield of pomegranate than basin irrigation (Sulochanamma *et al.,* 2005). Ramniwas *et al.* (2012) observed maximum fruit yield of guava at 100% irrigation water through drip system. The highest apple yield was 12.27 kg/ tree during 2002 and 13.10 kg/tree during 2004 obtained with 100% ETc (25.46 and 30.66%) as compared to basin irrigation (Banyal and Rehalia, 2008). Jain and Tiwari (2012) reported that number of fruit yield, fruit weight and fruits per plant were significantly highest with daily dripping as compared to alternate day dripping, ring system of irrigation and control. Pramanik and Patra (2015) reported that the drip irrigation registered significantly the higher banana fruit yield of 38.36 t/ha as compared to surface irrigation (35.96 t/ha). Kumar *et al.,* 2016 reported that with drip irrigation banana yield (115 MT/ha) increase was nearly 32 per cent as compared to soil application of fertilizers (78 MT/ha).

Effect of fertigation on yield attributes and nutrient use efficiency : Gutal *et al*. (2005) also recorded significantly higher yield of strawberry with fertigation as compared to soil application. Fertigation appreciably improved the apricot fruit yield over conventional soil fertilization (Raina *et al*., 2005). Drip-fertigation increases the nutrient use efficiency of crop by permitting timely application of fertilizers in small quantities in the vicinity of root zone matching with the plants' nutrient need, besides substantial saving in fertilizer usage and reducing nutrient losses (Kumar *et al.,* 2007). Mandal *et al.* (2007) observed that split application of N through drip irrigation enhanced

yield and nitrogen economy of crop. Increase in leaf N, P and K of strawberry plants with the application of higher dose of fertilizer under fertigated treatments have also been reported by Wold and Opstad (2007). Sharma *et al.* (2008) reported that fertigation was not only superior to conventional method in increasing the yield but also resulted in fertilizer savings up to 60 per cent and higher nutrient use efficiency in terms of grape yield kg/kg of applied nutrient. This fertigation on an average resulted in 173.5 per cent increase in case of N and K and 173.6 per cent increase in case of P over conventional method of fertilization. Fertigation with 100 and 75 per cent recommended dose of NPK fertilizer on an average increased the fruit yield of apricot by 16.4 and 13.7 per cent over soil fertilization (Raina *et al.,* 2011). Sharma *et al.* (2012) reported that the maximum increment in yield (14.4 and 8.1%) were found in the treatments I3 (Drip at 100% ETc) and N_2 (Drip at 100% of RDF) over control. Pawar and Dingre (2013) reported that 100 per cent recommended dose of fertilizer through drip as per crop growth stages showed 46.22 per cent increase in yield (83.62 t/ha). The banana fruit yield obtained under 60% fertigation (68 t/ha) produced 19% more yield as compared to conventional fertilizer application through soil (57.4 t/ha) indicating 40 per cent fertilizer saving due to fertigation. Kachwaya and Chandel (2015) reported that fertigation with ¾ of recommended dose of NPK registered 60 per cent higher fertilizer use efficiency over soil fertilization with full recommended dose of NPK and also resulted in 25 per cent saving of fertilizers without any adverse effect on growth, yield and fruit quality.

Effect of drip and fertigation on growth parameters :

Raina *et al.,* 2005 reported that fertigation with 100 and 80 per cent of recommended dosage and soil fertilization under irrigated conditions resulted in significantly higher growth parameters (annual shoot growth, tree growth and canopy volume) compared with soil fertilization under rainfed conditions. Martinsson *et al.* (2006) observed maximum plant height and number of leaves in plants fertigated with full nutrient package as compared to soil fertilization in strawberry. Drip irrigation at 100, 80 and 60 per cent ETc was found to enhance vegetative growth in terms of tree height, trunk girth, shoot extension growth, tree spread and tree volume compared to basin irrigation (Banyal and Rehalia, 2008). Highest flowering intensity, flower clusters per meter shoot length, fruit set and lowest fruit drop during two years were recorded in the treatment 100% ETc. Sadarunnisa *et al.,* 2010 reported that the growth components like no. of fruits/plant, fruit weight, fruit length and fruit volume were superior in the treatments where fertilizers were applied through drip compared to the treatments in which soil application of fertilizers was done. Raina *et al.* (2011) also recorded higher fruit size and weight of apricot fruits with 100 per cent of recommended dose of conventional fertilizers applied through fertigation. Fertigation, compared to granular fertilization, did not affect apple fruit number per tree, while individual fruit weight and length was reduced (Porro *et al.,* 2013). Haneef *et al.* (2014) reported that the treatment combination comprising 100 per cent recommended dose of fertilizers (RDF) and drip irrigation 100 per cent at alternate day (I_2F_2) resulted in higher profitable yield (net return Rs. 5,96,177/ha) with quality fruits.

Effect of drip and fertigation on quality parameters :

Patel and Patel (1998) reported that the increase in yield was mainly because of better growth, bigger size and more juice content in the fruits under drip-irrigated plants. Peterson (1998) observed better fruit size and overall quality in fertigated plot than the non-fertigated plants. Thakur and Singh (2004) recorded highest TSS and reducing sugar with 100% of recommended dose of NPK applied through drip irrigation. This increase in sugar content of fruits harvested from 100% recommended dose of NPK through drip might be due to more absorption of nitrogen which may have further exerted the regulatory role in affecting the fruit quality. Kumar and Pandey (2008) observed the highest values of TSS, total sugar content and reducing sugar in banana fruit with fertigation at 70 % RDF. Jeyakumar *et al.* (2010) also found that total sugar were comparatively higher in papaya fruits harvested from 100% recommended dose of N and K_2O through drip irrigation. The data also indicates that full and ¾ of recommended dose of NPK through drip significantly increased anthocyanin and ascorbic acid as compared to recommended dose of NPK through soil during both the years of study. Guava fruits from fertigated genotypes had slightly greater values of vitamin C content and ascorbic acid content when compared to those fruits obtained from the soil fertilized genotypes (Ramirez *et al.,* 2012). The TSS, pulp: peel ratio, acidity and organoleptic scores were observed to be improved due to drip and fertigation significantly as compared to conventional method of irrigation (Pawar and Dingre, 2013). Porro *et al.* (2013) reported that fertigation significantly improved quality apple fruit in comparison to granular application – fruit from fertigated trees had higher soluble solids concentrations (+0.35° Brix), firmer flesh (+0.22 kg/cm^2), and higher Thiault indices. Prakash *et al*., 2015 reported that application of water and nutrients through drip has made a remarkable effect on mango fruit quality in terms of total soluble solids (TSS), total sugars, ascorbic acid, total carotenoids and titrable acidity. Pramanik and Patra (2015) reported that relatively higher pulp and peel content, TSS, non-reducing sugar, total sugars, sugar/acid ratio and higher acidity was observed in drip irrigation as compared to surface irrigation. Improvement in guava fruit quality in terms of higher TSS (12.1°Brix), total sugars (6.61%), ascorbic acid (169.2 mg 100/g) and reduced acidity (0.27%) in T_3 was recorded as compared to less TSS (10.1°Brix), total sugars (6.12%), ascorbic

acid (159.6 mg 100/g) and high acidity (0.34%) in control trees (Singh *et al.,* 2015).

Effect of drip and fertigation on fruit cracking and sun burning : Ray *et al.* (2005) reported that sprinkler irrigation to replenish 100% evapo-transpiration (ET) resulted in highest yield and minimum fruit cracking in litchi. Fruit cracking and fruit drop in litchi was significantly reduced by different levels of fertigation treatments over control (Yadav *et al.,* 2011). Fallahi *et al.* (2013) reported that apple 'Fuji' trees with full sprinkler or full drip systems had lower sunburn incidence than those with other treatments and this may be resulted due to larger canopies more foliage and thus protected the fruit against direct heat. Mitra *et al.,* 2014 reported that sprinkler irrigation showed maximum percentage of normal fruits (97.83%) with lower percentage of sun-burnt (2.05%) and absence (0.00%) of cracked fruit in comparison to control (normal fruit 90.19%; cracked 2.58%; and burnt 7.48%).

Effect of mulching : Agrawal and Agrawal (2005) reported that all drip treatments either alone or in combination with mulches resulted in higher banana yield return than surface method of irrigation. Sharma *et al.,* 2005 reported that both the polyethylene and hay mulches were found effective in increasing the strawberry yield through their modifying effect on hydrothermal regimes of soil and also reduced nutrient losses due to weed control. Panigrahi *et al.* (2010) reported that drip irrigation with 60% V-volume of water + mulch recorded the maximum mango fruit yield (59.92 q/ha) as compared to other treatments and control (26.95 q/ha). Singh *et al.* (2015) also reported that application of black polyethene and hay mulch in surface irrigation, also increased the guava yield by 37.0 and 17.7 per cent respectively over unmulched plus surface irrigation treatment. Drip irrigation and black polyethylene mulching showed significantly high guava yield (16.92 kg/m^{-3}), number of fruits per tree (27.3/tree), and fruit weight (107.2 g) compared to minimum yield (8.21 kg/m^{-3}), number of fruits per tree (21.47/tree) and fruit weight (90.77 g) in control trees. Water saving of 47.52 per cent through mulching along with drip irrigation was also observed against mulched with basin irrigated trees (18.33%) vis-a-vis unmulched basin irrigation.

CONCLUSION

It is evident from the foregoing literature that drip irrigation, fertigation and mulching had many advantages like enhancement in fruit yield, improvement in growth parameters, increase in WUE and FUE. Uniform application of water to the root-zone of the plant helps in maintaining optimum moisture in the root zone and at the same time proper soil aeration is available. Drip fertigation helps in increasing the production and also lead to high profitable returns with quality fruits. Mulching can make effective change in increasing horticultural crop production in water scarcity regions. High initial investment and comparatively low technical skill of average Indian farmers are some of the major constraints limiting the large scale adoption as drip fertigation technology in the country. However, increasing water scarcity in high value crops, protected cultivation and ensuring greater efficiency of the two most critical inputs (water and fertilizer) in crop production leads to the adoption of these technologies.

REFERENCES

1. Agrawal, N. and Agrawal, S. (2005). Effect of drip irrigation and mulches on the growth and yield of banana cv. Dwarf Cavendish. *Indian J. Hort. 62(3) :* 238-240.
2. Anonymous. (2013). World health Organization. www.who.com
3. Bangar, A.R. and Chaudhary, B.C. (2004). Nutrient mobility in soil, uptake, quality and yield of Suru sugarcane as influenced by drip fertigation in medium vertisols. *J. Indian Soc. Soil Sci. 52 (2):* 164-171.
4. Banyal, S.K. and Rehalia, A.S. (2008). Effect of drip irrigation on growth, cropping and yield of apple under sub-temperate conditions. *Indian J. Hort. 65(3):* 268-271.
5. Bravdo, B. and Proebsting, E.L. (1993). Use of drip irrigation in orchards. *Hort. Tech. 3:* 44-49.
6. Fallahi, E.; Fallahi, B. and Shafii, B. (2013). Water Use, Mineral Nutrition, Tree Growth, Yield, and Fruit Quality of 'Fuji' and 'Gala' Apples under Various Irrigation Systems and Rootstocks Proc. VIIth IS on Mineral Nutrition of Fruit Crops Eds.: S. Poovarodom and S. Yingjajaval. *Acta Hort.* 984.
7. Fallahi, E.; Fallahi, B.; Shafii, B. and Morales, B. (2007). Water use, tree growth, and leaf mineral nutrients of young 'Fuji' apples as influenced by different irrigation systems. *Acta Hort. 721:* 63-70.
8. Gutal, G.B.; Barai, V.N.; Mane, T.A.; Purkar, J.K. and Bote, N.L. (2005). Scheduling of nitrogen through drip method of irrigation for strawberry. *J. Maharashtra Agri Univ. 30:* 215–6.
9. Hagin, J.; Sneh, M. and Lowengart-Aycicegi, A. (2002). Fertigation – Fertilization through Irrigation. IPI Research Topics No. 23. A.E. Johnston (ed.). International Potash Institute, Basel, Switzerland.
10. Haneef M.; Kaushik R.A.; Sarolia, D.K.; Mordia, A. and Dhakar M. (2014). Irrigation scheduling and fertigation in pomegranate cv. Bhagwa under high density planting system. *Indian J. Hort. 71(1):* 45-48.
11. Hedge, D.M. and Srinivas, K. (1990). Growth, productivity and water use of banana under drip and basin irrigation in relation to evaporation replenishment. *Indian J. Agron. 35(1-2):* 106-112.
12. Jain, P.K. and Tiwari, A. (2012). Effect of irrigation systems and frequencies on growth and yield of papaya. *Indian J. Hort. 69(2):* 277-280.
13. Jeyakumar, P.; Amutha, R.; Balamohan, T.N.; Auxcilia, J. and Nalina, L. (2010). Fertigation improves fruit yield and quality of papaya. *Acta Horti. 851:* 369–76.
14. Kachwaya, D.S. and Chandel, J.S. (2015). Effect of fertigation on growth, yield, fruit quality and leaf nutrients

content of strawberry (*Fragaria × ananassa*) cv Chandler. *Indian J Agric. Sci. 85 (10):* 1319–23.

15. Kumar, A.; Singh, R.K.; Sinha, A.K.; Singh, H.K. and Mishra, A.P. (2007). Effect of fertigation on banana through drip irrigation in North Bihar. *J. Res. Birsa Agric. Univ. 19 :* 81-86.
16. Kumar, D. and Pandey, V. (2008). Effect of NPK fertigation on growth, yield and quality of banana Rasthali' (AAB-Pathkapoora) in coastal agro-climatic conditions of eastern India. *Indian J. Agric. Sci. 78(9):* 798-800.
17. Kumar, M. S.; Ganesh, S.; Srinivas, K.; Panneerselvam, P. and Kasinath, B.L. (2016). Combining fertigation and consortium of bio-fertilizers for enhancing growth and yield of banana cv. Robusta (AAA). *Indian J. Hort. 73(1):* 36-41.
18. Mandal, G.; Kumar, S.; Kumar, R. and Singh, R. (2007). Effect of drip irrigation and plant spacing on yield, quality and economic return of guava (*Psidium guajava* L.) grown in saline soil. *Acta. Hort. (ISHS) 735 :4* 27-432.
19. Martinsson, M.; Kwast, A.; Cieslinski, G. and Treder, W. (2006). Impact of production systems and fertilizer application on yield and quality of strawberries. *Acta Horti. 708 :* 59– 64.
20. Mitra, S.K.; Ray, S.K.D. and Mandal, D. (2014). Control of Fruit Cracking and Sun-Burning in Litchi by Irrigation and Moisture Conservation. *Acta Hort.* 1024.
21. Mussaddak, J. (2007). Efficiency of nitrogen fertilizer for potato under fertigation utilizing a nitrogen tracer technique. Commun. *Soil Sci. Plant Anal. 38 :* 2401-2422.
22. Neilsen, D.; Millard, P.; Neilsen, G.H. and Hogue, E.J. (2001). Nitrogen uptake, efficiency of use and partitioning for growth in young apple trees. *J. Amer. Soc. Hort. Sci. 126 :* 144-150.
23. Neilsen, D.; Neilsen, G.H.; Gregory, D.; Forge, T. and Zebarth, B.J. (2008). Drainage losses of water, N and P from micro-irrigation systems in a young, high density apple planting. *Acta Hort. 792 :* 483-490.
24. Neilsen, D.; Smith, S.; Frank, G.; Koch, W.; Alila, Y.; Merritt, W.; Taylor, B.; Barton, M.; Hall, J. and Cohen, S. (2006). Potential impacts of climate change on water availability for crops in the Okanagan Basin, British Columbia. *Can. J. Soil Sci. 86 :* 909-924.
25. Padilla-Ramirez, J.S.; Cortés-Penagos, C.J.; Maldonado-Sierra, N.E. and Sánchez-Rico, T. (2012). Comparative Analysis for °Brix and Ascorbic Acid Concentration of Guava Fruits under Two Fertilization Treatments in Zacatecas, Mexico. *Acta Hort.* 959.
26. Panigrahi, H.K.; Agrawal, N.; Agrawal, R.; Dubey, S. and Tiwari S.P. (2010). Effect of drip irrigation and polythene mulch on the fruit yield and quality parameters of mango (*Mangifera indica* L.). *J. Hort. Sci. 5 (2):* 140-143.
27. Patel, N.M. and Patel, M.M. (1998). Water requirement of pomegranate (*Punica granatum* L.) cv. Ganesh for better yield under resources limited situations. National Seminar on new horizons in productionand post harvest management of tropical and subtropical fruits, Delhi, 8-9.
28. Pawar, D.D. and Dingre, S.K. (2013). Influence of fertigation scheduling through drip on growth and yield of banana in western Maharashtra. *Indian J. Hort. 70(2):* 200-205.
29. Peterson, O.V. (1998). Influence of raised beds, plant density and fertigation on yield and quality of strawberry (*Fragaria x ananassa* Duch.). *Gartenbau Wissenschaft 63:* 19–22.
30. Porro, D.; Pantezzi, T.; Pedo, S. and Bertoldi, D. (2013). Interaction of Fertigation and Water Management on Apple Tree Productivity, Orchard Nutrient Status, and Fruit Quality Proc. VIIth IS on Mineral Nutrition of Fruit Crops Eds.: S. Poovarodom and S. Yingjajaval. *Acta Hort.* 984.
31. Prakash, K.; Vijayakumar, R.M.; Balamohan, T.N. and Singh, S.D.S. (2015). Effect of Drip Irrigation Regimes and Fertigation Levels on Yield and Quality of Mango Cultivar 'Alphonso' under Ultra High Density Planting. *Acta Hort.* 1066.
32. Pramanik S. and Patra K.S. (2016). Growth, Yield, Quality and Irrigation Water Use Efficiency of Banana under Drip Irrigation and Fertigation in the Gangetic Plain of West Bengal. *World J. Agric. Sci. 12 (3):* 220-228.
33. Pramanik, S. and Patra, S.K. (2015). Effect of drip vis-à-vis surface irrigation on fruit yield, nutrient uptake, water use efficiency and quality of banana in Gangetic plain of West Bengal. *Indian J. Hort. 72(1):* 7-13.
34. Pramanik, S.; Ray, R. and Patra, S.K. (2014). Effect of drip vis-à-vis surface irrigation on fruit yield, water use and distribution efficiency of banana in Gangetic plain of *West Bengal Indian J. Hort. 71(2):* 176-183.
35. Raina, J.N.; Sharma T. and Shashi, S. (2011). Effect of drip fertigation with different fertilizers on nutrient distribution in soil, leaf nutrient content and yield of apricot (*Prunus aremeniaca* L.). *J. Indian Soc. Soil Sci. 59:* 268-277.
36. Raina, J.N.; Thakur, B.C.; Suman, S. and Spehia, R.S. (2005). Effect of Fertigation Through Drip System on Nitrogen Dynamics, Growth, Yield and Quality of Apricot Proc. VIIth on TZFTS Eds. J.S. Chauhan et al. *Acta Hort.* 696.
37. Ramniwas, R.A.; Kaushik, D.K.; Sarolia, S.P. and Singh, V. (2012). Effect of irrigation and fertigation scheduling on growth and yield of guava (*Psidium guajava* L.) under meadow orcharding. *Afri. J. Agri. Res. 7(47):* 6350-6356.
38. Ray, P.K.; Ruby, R. and Singh, S.K. (2005). Fruit cracking in litchi in relation to sprinkler irrigation. *Indian J. Agric. Sci. 75(2) :* 97-99.
39. Sadarunnisa, S.; Madhumathi, C.; Hari Babu, K.; Sreenivasulu, B. and Rama Krishna, M. (2010). Effect of Fertigation on Growth and Yield of Papaya cv. Red Lady. *Acta Hort.* 851.
40. Seckler, D.; Amarasinghe, U.; Molden, D.; Radhika and Barker, R. (1998). World water demand and supply, 1990 to 2025: Scenarios and Issues, Research Report 19, *International Water Management Institute*, Columbo, Sri Lanka.
41. Sharma, I.P.; Kumar, S. and Kumar P. (2005). Effect of Drip Irrigation and Mulches on Yield, Quality and Water-use Efficiency in Strawberry under Mid Hill Conditions. *Acta Hort.* 696.
42. Sharma, J.; Upadhyay, A.K.; Shikhamany, S.D. and Singh, R.K. (2008). Effect of Fertilizer Application through Irrigation Water on Thompson Seedless Grape Yield and Fertilizer Use Efficiency. *Acta Hort.* 785.
43. Sharma, S.; Halder, A.; Patra, S.K. and Ray, R. (2012). Effect of drip irrigation and nitrogen fertigation on water

use efficiency (WUE) and cost economics of guava cv. Khaja. *Prog. Hort. 44(1)*: 136-141.

44. Sharma, S.; Patra, K.S.; Roy, B.G. and Bera, S. (2013). Influence of drip irrigation and nitrogen fertigation on yield and water productivity of guava. The Bioscan – *An International Quartley J. Life Sci. 8(3):* 783-786.
45. Singh, D. and Sharma, V. (2013). Impact of micro-irrigation practices on farmers economy of Kullu district in Himachal Pradesh. *Prog. Hort.* 45(2).
46. Singh, V.K.; Soni, M.K. and Singh, A. (2015). Effect of drip irrigation and polyethylene mulching on fruit yield and quality of guava cv. Allahabad Safeda under meadow orcharding. *Indian J. Hort. 72(4):* 479-484.
47. Sulochanamma, B.N.; Reddy Y.T. and Reddy S.G. (2005). Effect of Basin and Drip Irrigation on Growth, Yield and Water Use Efficiency in Pomegranate cv. Ganesh. Acta Hort. 696.
48. Thakur, S.K. and Singh, P. (2004). Studies on fertigation of mango cv. Amarpali. *Annals Agric. Res. 25:* 415–7.
49. Verma, M.L.; Thakur, B.C. and Bhandari, A.R. (2007). Effect of drip irrigation and polyethylene mulch on yield, quality and water-use efficiency of peach cv. July Elberta. *Indian J. Hort. 64(4):* 406-409.
50. Wold, A.B. and Opstad, N. (2007). Fruit quality in strawberry\ (Fragaria × ananassa Duch. cv. Korona) at three times during the season and with two fertilizer strategies. *J. Applied Bot. and Food Quality 81:* 36–40.
51. Yadav, P.; Lal, R.L. and Pandey, C. (2011). Effect of different levels of fertigation on yield, quality and leaf nutrient status of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. *Prog. Hort. 43(2):* 276-280.

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