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Fertigation in Horticultural Crops

(Sougata Das, *Aritra Gangopadhyay and Arijit Bera)
School of Agriculture, Lovely Professional University, Phagwara-144401, Punjab, India
*Corresponding Author's email: aritraj264@gmail.com

Doubling the farmers' income through maximizing production per unit drop of water and sustaining soil health is the national goal. Horticulture sector is currently witnessing paradigm shift from 'yield maximization' to 'enhancement of use efficiencies of irrigation water and nutrients. Emphasis is on reducing excessive percolation of water along with precious nutrients beyond rhizosphere. Drip-fertigation system has been found to be very effective in achieving the judicious water and fertilizer use efficiency in horticultural crops. In the present-day context, lot of emphasis is being given on improving the drip-fertigation practices for horticulture, where the crops are highly responsive to the need-based placement of water and nutrients. Adopting drip-fertigation has been found to increase the yields of horticultural crops by three-fold with the same quantities of water and nutrients. It has also been found to improve the quality of crop produce and help the growers in getting better prices for their produce. Savings on irrigation water and fertilizer under drip-fertigation are 40-70% and 30-50%, respectively. Critical review of the research outcomes emanating from drip-fertigation strategy in horticultural crops is done in this paper.

Introduction

Water and fertilizer are the two major inputs for crops and interact with each other in influencing growth, yield and quality of crops. As most of the horticultural crops are water- and nutrient- exhaustive in nature, efficient management of these precious inputs is a must for achieving higher productivity but maintaining environmental quality. India is blessed with diverse agro-climatic conditions with distinct seasons, making it possible to grow wide array of horticultural crops. Besides, sustained higher yields with high yielding varieties depend entirely on the sustainable use of the limited water and energy resources, specifically in water-scarce arid and semiarid regions. There is an urgent need to reduce the consumption of irrigation water by adopting effective water-saving technologies and methods. The increasing demands for irrigation water and fertilizers and their exorbitant costs call on adopting judicious, efficient, and eco-friendly use of these inputs in horticultural crops. Every effort must be made to enhance water and fertilizer use efficiency by reducing their wastage. In recent years, drip fertigation has been used for applying water soluble fertilizers through drip irrigation. Drip irrigation achieves up to 90% per cent irrigation efficiency, generally increases the crop yields to the tune of 25 to 30% and incurs 30% to 50% savings on irrigation water over conventional irrigation methods. The fertigation allows application of right amounts of plant nutrients uniformly to the wetted root volume zone, where most of the active roots are concentrated and this helps in enhancing the nutrient use efficiency. It has been found to improve the productivity and quality of crop produce in addition to improving the resource use efficiency. Fertigation, a synergistic approach, saves up to 25% on fertilizers. As the water-soluble fertilizers are very costly inputs, efforts have been made by various researchers to reduce the quantity of water-soluble fertilizers [nitrogen (N) and potassium (K)] in conjunction with straight fertilizer (single superphosphate, SSP) to enhance the yield potentials of crops and improve the fertilizer use efficiency. Key focus of this article is to discuss the importance and potential of drip fertigation technology for achieving higher productivity and maximizing the resource use efficiency in horticultural crops.

Fertigation

Fertigation is a technique of fertilizer application in which fertilizer is incorporated within the irrigation water by the drip system where timing, amounts and concentrations of fertilizers applied are easily controlled. Fertigation ensures saving in fertilizer (30- 50%), due to "better fertilizer use efficiency" and "reduction in leaching". Drip irrigation is often preferred over other irrigation methods because it gives higher water application efficiency by reducing water losses through surface evaporation and deep percolation. Because of high frequency of water applications, concentrations of salts remain manageable in the rooting zone. In the present situation, water has become a scarce natural resource for agriculture due to competition caused by rapid industrialization, population growth, and urbanization. There is an urgent need to reduce the consumption of irrigation water by way of developing new irrigation-efficient technologies and methods that help in effective utilization of this precious input. As mentioned above, drip fertigation is a type of micro irrigation that has the great potential to save on water and nutrients by allowing water to drip slowly to the roots of plants and minimize evaporation. Drip fertigation reduces the wastage of water and chemical fertilizers and optimizes the nutrient use by applying them at critical stages and at proper effective root zone and time, which finally results in the increased water and nutrient use efficiencies. It is recognized as the most effective and profitable means of maintaining optimal nutrient level and water supply according to crop development stage, specific needs of crop and type of the soil.

Significance of Fertigation in Horticulture

In India, most of the horticultural crops are being cultivated on raised beds, with soil texture ranging from loamy clay to sandy loam, where downward percolation of water is rapid and often leads to leaching of nutrients beyond root zone under the conventional irrigation methods. Under such soil conditions, frequent occurrences of the deficiencies of macro and micronutrients become a major production constraint exacerbated by the low moisture and nutrient holding capacities of these soils. Under conventional method of irrigation, rapid hydraulic conductivity, faster infiltration rate cause accelerated leaching of basic cations to the lower layers (below root zone). Net result is deterioration of soil fertility. This condition may load the ground water with pollutants like leached down fertilizer salts, other toxic pesticides, herbicides etc. Hence, the horticultural crops in such soils under conventional irrigation system require large quantities of nutrients to support its growth and yield for compensating the leaching losses of nutrients. Considering the soil and crop constraints, nutrients should be applied in synchrony with crop demand in smaller quantities during the growing season. The right combination of water and nutrients is a prerequisite for higher yield and good quality of produce. Method of fertilizer application is also important in improving the use efficiency of nutrients. Fertigation is the only irrigation strategy, which helps in adequate supplies of water and nutrients with precise timing and uniform distribution to meet the nutrient demand of horticultural crops. Besides, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses.

Fertigation Scheduling

Factors that affect fertigation scheduling for horticultural crops are soil type, available nutrient status, organic carbon, soil pH, soil moisture at field capacity, available water capacity range, aggregate size distribution, crop type and duration and its physiological growth stages, and discharge variation and uniformity coefficient of installed drip irrigation system. The efficient fertigation schedule needs to consider

I) crop- and site- specific nutrient management,
II) timing and frequency of nutrient delivery to meet crop needs at critical growth stages, and
III) controlling irrigation to minimize leaching of soluble nutrients below the effective root zone.

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

Response to Fertigation in Different Horticultural Crops

Fruit crops

Sl. No	Fruit crops	Fertigation requirement	Crop response	Reference
1.	Mango (*Mangifera indica* L.) Variety: Dasha Hara 10 m x 10 m spacing	75% RDF (380 g N-380 g P2 O5 -380 g K2 O per tree) + mulch + drip irrigation in V-area of basin in 16-year-old orchard	Increase in growth yield and quality, in addition to soil fertility	Panwar *et al.* (2007)
2.	Mango (*Mangifera indica* L.) Variety: Alphonso 2.5 m x 2.0 m spacing	100% RDF (120 g N- 100 g P2 O5 -100 g K2 O per tree) + 24 liters water per day in a 3-year- old orchard	Increase in fruit yield and quality	Prakash *et al.* (2015)
3	Mango (*Mangifera indica* L.) Variety: Dasha Hara 10 m x 10 m spacing	75% RDF (750 g N-375 g P2 O5 -750 g K2 O per tree) + 100% irrigation through drip based on 0.60W/CPE ratio in 30-year-old orchard	Improvement in nutrition distribution, nutrient use efficiency coupled with better soil moisture distribution and yield	Adak *et al.* (2014)
4.	Guava (*Psidium guajava* L.) Variety: Shweta 2 m x 1 m spacing	75% RDF (30 g N-10 g P2 O5 -10 g K2 O per tree) + 75% irrigation requirement based on CPE in 3-year-old meadow orchard	Increase in flowering leaf nutrient status, growth, yield and quality	Ramniwas *et al.* (2013)
5.	Guava (*Psidium guajava* L.) Variety: Shweta	100 RDF + surface drip irrigation at 1.0 IW/CPE ratio	Increase in growth and fruit yield response	Sharma *et al.* (2013)

	2 m x 1 m spacing			
6.	Pomegranate (*Punica granatum* L.) Variety: Bhagwa 2 m x 2 m spacing	100% RDF (200 g N-200 g P2 O5 -500 g K2 O per tree using water soluble 19:19:19 fertilizer) + 100% irrigation at alternate day through drip irrigation in 4-year-old orchard	Better soil moisture distribution, fruit yield and quality	Haneef *et al.* (2014)
7.	Pomegranate (*Punica granatum* L.) Variety: Mridula 2 m x 2 m spacing	50% RDF using water soluble fertilizer + drip irrigation at 100% CPE in 2-year- old orchard	Improvement in flowering, soil available nutrients and fruit yield	Shanmugasundaram *et al.* (2013)
8.	Almond (*Prunus dulcis* L.) Variety: Waris	75% RDF (330 g N-45 g P2 O5 -455 g K2 O per plant through water soluble fertilizers) + drip irrigation based on pan evaporation in 8- year-old orchard	Increase in growth response and yield in addition to soil fertility	Dinesh Kumar and Almed (2014)
9.	Banana (*Musa paradisica* L.) Variety: Robusta	100% RDF (200 g N- 110 g P2 O5 - 200 g K2 O plant-1 crop-1) fertigation along with microbial consortium (Azospirillum, phosphate solubilizing bacteria and AM fungi mixed in equal proportions)	Increase in uptake of secondary nutrients and micronutrients besides fruit yields	Senthil Kumar *et al.* (2014)

Vegetable crops

Sl. No	Vegetable crops	Fertigation requirement	Crop response	Reference
1.	Tomato (*Solanum lycopersicum* L.)	75% RDF (262.2 kg N-40.4 kg P2 O5 and 90.5 kg K2 O/per ha), using MAP, Multi K and urea in surface drip irrigation	Improved fruit yield, higher leaf area index. Root growth and NPK uptake was higher with fertigation.	Kalanjiyam and Manickam (2015)
2.	Potato (*Solanum tuberosum* L.)	100% RDF (50% nitrogen (N) mineral,10 t/fed compost + humic substances, 10 t/fed compost + effective microorganism (EM) 4 L hr-1	Highest tuber potato quality and quantity in sandy soil conditions	Mohamed *et al.* (2014)
3.	Cabbage (*Brassica oleracea* L.)	100% RDF (254.4 kg N, 19.1 kg P2 O5 and 324 kg K2 O ha-1) along with surface irrigation at IW/CPE ratio of 1.0	Increase in head diameter. TSS and ascorbic acid content was highest at 125% RDF but B:C ratio of 3.03 was recorded in daily fertigation with 100% RDF.	Vasu and Reddy (2013)

4.	Chili (*Capsicum annuum* L.)	RDF: 100 kg N – 50 kg P2 O5 –50 kg K2 O per ha at irrigation of 1.0 PE (40.18 days)	Increase in number of leaves, plant height and yield response	Chaurasiya and Sahu (2016)
5.	Cauliflower (*Brassica oleracea* L.) transplanted at 0.60 m x 0.60 m	RDF: 225 kg N - 75 kg P2 O5 - 75 kg K2 O per ha with irrigation @ 2.0 L hr-1 flow rate at 100 kPa pressure (KCP 0.75-1.25)	Improved yield and significant difference in curd weight and diameter, yield, AGB, number of leaves per crop and curd weight/AGB ratio.	Bozkurt *et al.* (2011)
6.	Brinjal (*Solanum melongena* L.) S3 (175 cm- 50 cm x 50 cm) plant spacing	80% RDF (150 kg N: 50 kg P2 O5: 50 kg K2 O ha 1), IW/CPE ratio of 1.0 irrigation level – 0.6 PE.	Significantly higher value of total N, P and K uptake, maximum fertilizer-use - efficiency of NPK and yield	Ugade *et al.* (2013)

Plantation crops

Sl. No	Plantation crops	Fertigation requirement	Crop response	Reference
1.	Cocoa (*Theobroma cacao* L.)	125% RDF (125 g N+ 50 g P2 O5 + 175 g K2 O per plant per year) with irrigation of 20 L per tree per day	A phenomenal increase in growth parameters such as trunk girth, canopy spread and weight of the pruned branches removed, leaf fresh weight and leaf dry weight as well as levels of NPK	Krishnamoorthy *et al.* (2013)
2.	Arecanut (*Areca catechu* L.)	75% NPK (RDF: 100 g N: 18 g P2 O5: 117 g K2 O per palm per /year) along with irrigation at IW/CPE ratio of 1 with a 30 mm depth of water through basin irrigation	Increase in leaf water potential, root biomass and organic carbon content in soil based on polynomial regression as well as significant increase in water use efficiency and agronomic nutrient use efficiency	Bhat *et al.* (2007)

Benefits of Fertigation

Use efficiency of applied nutrients in crops is greater under fertigation compared to that under conventional application of fertilizers to the soil. Intensification of agriculture led by use of irrigation water and indiscriminate use of fertilizers has led to the pollution of surface and ground waters by nutrients added through the chemical's fertilizers. Fertigation helps in i) lessening the pollution of water bodies by arresting the leaching or surface run-off of the nutrients such as N and K out of agricultural fields, and ii) saving of water, nutrients, energy, Laboure and time. It provides flexibility in field operations. For example, nutrients can be applied to the soil even under situations where crops or soil conditions would otherwise prohibit entry into the field with conventional equipment. Fertigation offers opportunity for efficient use of compound and ready-mix nutrient solutions containing small concentrations of micronutrients, which are otherwise very difficult to apply accurately to the soil when applied alone. When fertigation is applied through the drip irrigation system, crop foliage can be kept dry, thus avoiding leaf burn and delaying the development of plant pathogens. Fertigation helps to reduce weed menace, particularly between the crop rows. Use of plastic mulch along with fertigation through drip system allows effective weed control in widely spaced crops. The ability of micro irrigation system to irrigate undulating soils makes it possible to bring such lands under cultivation, which otherwise remain as wastelands or used as pasture lands. In micro irrigation systems reduced need for surface traffic movement during irrigation and nutrient application helps in reducing the soil compaction.

Conclusions

Fertigation system is an efficient method of applying fertilizers in which the irrigation system is used as the carrier and distributor of the crop nutrients. The combination of water and nutrients leads to an efficient use of both by the crop plants. The use of fully soluble fertilizers seems more economical in the first stages when fertigation is adopted, but the use of prepared clear liquid solutions is very convenient in other cases. Fertigation system is very suitable for commercial horticulture where maximization of profitability and yields is a target. Fertigation has been found to be one of the most successful ways of water and nutrient application, particularly N, K, and micronutrients through drip system. Besides increasing the economic yields, fertigation helps in proper utilization of fertilizer nutrients, saves labor, and increases productivity. Yield advantages have been reported across the wide range of crops under diverse agroclimatic situations. Fruit and vegetable crops have been found to be responsive to fertigation due to their wide spacing nature, continuous need of water and nutrients at optimal rate to give high yields with good quality, and high capital returns on the investments. Even though the initial cost of establishing the fertigation system is higher but on long-term basis it is economical compared to conventional methods of fertilization as it brings down the cost of cultivation. However, to get the desired results, it requires higher management skills at operator level like selection of fertilizers, timing and rate of fertilizer injection, watering schedule, as well as the maintenance of the system. Therefore, to make the horticulture sustainable and economically viable and to ensure food and nutritional security of the burgeoning population there is a need to promote the fertigation at large scale by all the concerned stakeholders.

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