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Review Article

Innovative Approaches for Improving Water Productivity in Fruits Crops

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ABSTRACT

Among the various factors which affect the production and productivity of fruit crops, nutrient and water assume more significance. Since majority of the fruit crops in India are grown under water scarcity conditions, economising the limited water available through improved micro irrigation systems invariably enhances the productivity and quality of fruit crops. The concept of fertigation in perennial crops has given a definite edge over conventionally used basin method of irrigation coupled with basal or top dressing of fertilizers within the perimeter of trees. Mulching is very useful in protecting the roots of the plants from heat and cold and is used to cover soil surface around the plants to create congenial condition for the growth especially under rainfed conditions. Based on the research work carried out at ICAR-IIHR over the years, the fertigation schedule for important fruit crops of the region have been worked out. Partial root zone drying irrigation in papaya meeting 80% replenishment of evaporation even with one emitter per plant resulted in significantly higher number of fruits (54/plant) and higher water productivity (23.7 kg/m^3) could be obtained by scheduling the irrigation at 40% evaporation replenishment through shifting of laterals at fortnightly intervals. Further, higher papaya yield (48.0 t/ha) was recorded with normal drip irrigation (wetting 80% soil volume) under closer spacing (1.5 m x 1.5 m). Sensor based irrigation technologies with energy of the system provided by solar power and controlled by smart phones increases the usability of the system.

Keywords: Fertigation, fruit crops, mulching, sensor, solar power, water productivity

INTRODUCTION

Life on earth started with water. Food is grown in various parts of the world according to the climatic conditions but one thing that all kinds of crops need without an exception is water. We all know how water, sunlight and nutrition from the soil are key to a plant's growth. Most water bodies (stream, lake, estuary, wetland, aquifer) have been designated for a specific use(s) like aquatic life, fish for consumption, drinking water supply, swimming and other high contact recreation, boating and other minimal contact recreation, agricultural (irrigation/livestock), industrial uses, etc. India with 2.4% of the world's total area has 16% of the world's population; but has only 4% of the total available fresh water. This clearly indicates the need for water resource development, conservation, and optimum use. Fortunately, at macro level India is not short of water. The problems that seem to loom large over the sector are manageable and the challenges facing it are not insurmountable. While the total water resource availability in the country remains constant, the per capita availability of water has been steadily declining since 1951 due to population growth. The twin indicators of water scarcity are per capita availability and storage. A per capita availability of less than 1700 cubic metres (m^3) is termed as a water-stressed condition while if per capita availability falls below 1000 m^3, it is termed as a water scarcity condition. While on an average we may be nearing the water-stressed condition, on an individual river basin-wise situation, nine out of our 20 river basins with 200 million population are already facing a water-scarcity condition.

Water Productivity of Fruit Crops

Among the various factors which affect the production and productivity of fruit crops, nutrient and water assume much more significance. These two inputs are essentially required to be managed in a manner, which provides maximum output. Inadequacy of one or other inputs at critical stage of fruit development, adversely affect the productivity and quality of produce. Therefore, it is required that these inputs are effectively managed. Success in commercial fruit culture depends on availability of rain or supplemental irrigation particularly during critical periods of tree growth and development. As vast majority of fruit cultivation is under rainfed production system and water shortage is an important limiting factor of production in many regions of the country, scientific management of water can maximize the productivity and increase the water use efficiency of these fruit orchards. Further, development and adoption of efficient water management practices are of great importance both in rainfed and irrigated orchards. Studies were carried out on water management practices of fruit crops in different regions of the country and the results are varying depending on the climatic conditions and the crops. As such, efficient utilization of the available scarce water resources assumes greater significance.

Water use efficiency, fruit yield and quality were the integrated response of crop to soil water distribution, physiological index and water relations. Water and nutrient management assumes special significance in the productivity of fruit crops. Deficiency of any one of these inputs at any of the growth and development stage of fruit crops will adversely affect the overall production and quality. Hence, these inputs need to be efficiently managed for higher water and nutrient use efficiency.

Since majority of the fruit crops in India are grown under water scarcity conditions, economising the limited water available through improved micro irrigation systems invariably enhances the productivity and quality of fruit crops. Apart from this, the productivity of major tropical fruits are low due to improper fertilizer management practices. Adoption of drip irrigation system enables the introduction of desired fertilizers into the system in required quantities for better utilization. Fertigation aids in delivering both the fertilizers and water to the root system thus, economizing the applied inputs. Plants exposed to uniform regime of moisture and nutrients in the rhizosphere will have an added advantage of spending lesser energy for uptake of these inputs.

Since the wetting zone is restricted under drip irrigation, it becomes imperative to apply the fertilizers in the wetted zone for better recovery. Intensive growing of perennial fruit crops under high density and ultra high density plant population has further put an additional pressure on soil fertility conservation. But, concept of fertigation in perennial crops has given a definite edge over conventionally used basin method of irrigation coupled with basal or top dressing of fertilizers within the perimeter of trees. A plant exposed to uniform regime of moisture and nutrient flow within rhizosphere zone has to spend much less energy than the growing conditions constantly changing over time. Fertigation, is thus, energy efficient as well. This has led to an increase in both fertilizer use efficiency and water use efficiency. Reports are candidly visible on fruit yield, quality indices, soil fertility improvements coupled with water use efficiency and fertilizer use efficiency covering a variety of fruit crops (Shirgure and Srivastava, 2014. Hence, fertigation has proved beyond doubt about its utility to fruit culture. However, the quantity of fertilizers to be applied (including speciality fertilizers) at different crop growth stages in appropriate ratios has not been standardized for important fruit crops.

To cope with the scarce supplies, deficit irrigation, defined as the application of water below full crop-water requirements (evapo-transpiration), is an important tool to achieve the goal of reducing irrigation water use. While deficit irrigation is widely practiced over millions of hectares for a number of reasons—from inadequate network design to excessive irrigation expansion relative to catchment supplies—it has not received sufficient attention in research. Its use in reducing water consumption for biomass production and for irrigation of annual and perennial crops needs to be highlighted. There is potential for improving water productivity in many crops and there is sufficient information for defining the best deficit irrigation strategy for many situations. One conclusion is that the level of irrigation supply under deficit irrigation should be relatively high in most cases, one that permits achieving 60–100% of full evapo-transpiration. Several cases on the successful use of regulated deficit irrigation (RDI) in fruit trees and vines have showed that regulated deficit irrigation (RDI) not only increases water productivity but also farmers' profits. Research linking the physiological basis of these responses to the design of RDI strategies is likely to have a significant impact in increasing its adoption in water-limited areas (Elias Fereres and Marý´Auxiliadora Soriano, 2007).

Rainfed Production Technology for Fruit Crops Production

Standardisation of rainfed production technology for suitable fruit crops assumes practical significance in the wake of its vast potential. A strategy that ensures acceptable use of the available resources presumes that the limited resources are efficiently used so that the benefits per unit output are optimized. The crop that is imposed to varying levels of moisture may show diverse responses in terms of effect of water stress on plants at physiological, biochemical and molecular levels and these three response levels according to the severity and timing of the water stress (Critchley and Siegert, 1991). Mulching is very useful in protecting the roots of the plants from heat and cold and is used to cover soil surface around the plants to create congenial condition for the growth. The advantages of mulching include temperature moderation, reduction in salinity and weed control, decisive effects on earliness, yield and quality of the crop. Mulching can be practiced in fruit crops like guava using crop residues and other organic material available in the farm. It aids in efficient soil and moisture conservation, weed suppression and maintenance of soil structure, improved yield and quality (Bhardwaj and and Lal 2013). Reflective mulches not only improve the use efficiency of applied fertilizer nutrients but also only likely to minimize the incidence of virus diseases. Generally raised bed with drip irrigation system is followed while laying the mulch film. The application of black plastic mulch film is becoming popular and very good results have been achieved particularly in arid and semi-arid regions (Bhardwaj and and Lal 2011). Black polyethylene film (100 micron thick) is also known to help in conservation of moisture and increase root growth, flowering and fruiting and minimise fruit drop with enhancement in yield.

Field experiments were conducted during 2015-17 at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru to standardize *in situ* soil and moisture conservation measures in rainfed guava production. The results indicated that the mulching with polythene recorded 111% more moisture differing significantly from the control (no mulching) indicating its superiority in conserving the soil moisture *in situ*. The impact of the treatments was much visible for longer periods (160 days) after cessation of rainfall. Further, the increased moisture with polythene mulching favoured higher microbial activity inturn improving the overall soil fertility. Higher soil organic carbon built up (from 0.68 to 0.92 % O.C. over a period of three years) was observed with polythene mulching. It was also reflected in the nitrogen content of the soil which increased from 109.4 to 354.8 kg/ha during three years period. Polythene mulching with raised soil around the root zone showed 39.8 % higher fruit yield in guava over control on three years pooled mean basis. The treatment recorded 12.30 t/ha at sixth year of guava planting. Mulching with polythene although recorded slightly lower gross returns (Rs.6,19,870/ha), recorded higher benefit cost ratio (1:5.25) and was followed by mulching with enriched coir pith (1: 4.83) (Manjunath *et al*., 2019).

Rainfed Mango Production through Integrated System Approach

In one ha mango garden, which were planted at a spacing of 10m x 10m, without disturbing the plants, the middle 5m between two plant lines can be used for farm pond construction leaving 2.5m on either side for the mango root growth. With a depth of 10 feet (3.3m) in trapezoidal shape of the farm pond having a side slope of 1:1.5, the evaporation losses were only minimal owing to partial shading from mango trees as well as due to limited width of the farm pond reducing the air movement at the water surface. With the inter-space available in mango -5 m as the top width and length 45 m (the space of 6 mango plants on either side spaced at 10m x 10m), the storage capacity exceeded five lakh litres. Silpaulin lining with 750 gsm was covered for farm pond to prevent the seepage losses. The farm pond water thus stored was used for vermi composting maintenance which worked out to 3600 litres/year and for life saving irrigation to both drumstick and curry leaf. The stored water can also be used for the maintenance of dairy animals (two numbers) /year for two cows. Leaving about 30% of the total storage towards evaporation, a total quantity of 2,35,150 litres out of five lakh litres was available for protective irrigation. The available water was used for growing of high value crops around the farm pond area and for the protective irrigation to the base crop- mango at fruit initiation and development stage and for intercrops in their critical stages. For 100 plants of mango grown in a hectare with a normal spacing of 10 m x 10m, to wet the soil profile of the root zone to field capacity levels, it is estimated that about 600 litres of water per plant twice coinciding with the critical stages of fruit initiation and fruit development stages, the total quantity of water worked out to 1,20,000 litres which was available within the stored water of farm pond. The remaining water of about 1,15, 000 litres was used for protective irrigation to sweet corn and dolichus in about 1050 m^2 each. The cost economics of water harvesting pond indicated that the total cost including soil excavation through JCB, Silpaulin sheet (300 gsm) lining and shade net protection round the pond costed Rs. 1, 84, 000. This works out to about Rs. 0.37/litre of water stored.

Fertigation Scheduling for Different Fruit Crops

Based on the research work carried out at ICAR-IIHR over the years, the fertigation schedule for important fruit crops of the region have been worked out and the same is presented in Table1. While the drip irrigation schedule can be practiced depending on the ET values of the season and the sensitivity of the crop phenological stages, the schedule of recommended fertilizers can be followed based on the crop and the specific age with provision for refinements based on soil test values.

Partial Root Zone Drying Irrigation

Vegetative vigour is a major problem for many fruit crops, since the use of assimilates in leaf growth restricts fruit set and development (Morison *et al.,* 2008). Partial rootzone drying (PRD) deliberately irrigates only part of the root zone, while the remainder is allowed to dry. Alternating these wet and dry zones (thus re-wetting dry soil) substantially improves crop yields compared with maintaining fixed wet and dry zones or conventional deficit irrigation and modifies phytohormonal (especially abscisic acid) signaling. Partial root drying technique has the potential to reduce crop water use significantly and maintain the yields. Irrigating part of the root system keeps the leaves hydrated while drying on the other part of the root system promote synthesis and

Table 1: Fertigation schedule for major fruit crops of the region during economical growing period

Crop	Spacing	FYM	Recommended Fertilizers (RDF) (g NPK / plant/ year)	Drip irrigation Schedule at	Fertigation with water soluble fertilizers	Biofertilizers/ others	Additional care
Mango	10 m x 10 m	25 t/ha	738:180:680	60% ER (15-18 litres/day during flowering to fruit development) and no irrigation 2 months prior to flowering	75% RDF in the ratio 2-1-0 (July- August), 2-2-2 (September-November), 0-1-1 (December-January) and 0-0-2 (February-April).	300g Biofertilizer consortia	Mango special @ 4g/litre of water- four times
	5 m x 5 m	25 t/ha	738:180:680	60% ER(15-18 litres/day during flowering to fruit development) and no irrigation 2 months prior to flowering	75% RDF in the ratio 2-1-0 (July- August), 2-2-2 (September-November), 0-1-1 (December-January) and 0-0-2 (February-April).	300g Biofertilizer consortia	Mango special @ 4g/litre of water- four times
Banana	1.8 m x 1.8m	25t/ha	200g N, 100 g P_2O_5 and 200 g K_2O/plant/crop For ratoon crop, the requirement of N, P_2O_5 and K_2O remains the same as that of the main crop	80% ER (20-25 litres/ day during summer and 50% less during other months)	Nitrogen and potash are to be applied in equal split doses while that of phosphorus can be applied at the time of planting.	Nutrient feeding through the distal end of the bunch peduncle after the removal of tassel with fresh cow dung slurry and 5-7g urea dissolved in it; is filled in a polythene bag (usually half liter milk sachet) and tied to the bunch end immediately after denavelling.	Banana special, a micro nutrient formulation developed by IIHR consist mainly of six micro nutrients viz., zinc, iron, boron, copper, manganese and molybdenum and three secondary nutrients viz., calcium, magnesium and sulphur is also recommended as a foliar spray from 4/5th month of planting at monthly interval on the whole plant till the bunch formation and there after two sprays on the bunches. Spray solution is prepared by dissolving 75 g of banana special in 15 litres of water (about 12 kg/acre), for correcting the micro nutrient deficiencies.
Sapota	8 m x 8 m	40 kg/ plant	1-3 years 250:125:125; 4-6 years 500:250:250; 7-10 years 1000:500:500; 11 years and above 1000:500:750	40 to 50 liters of water per day during summer months and the quantity can be reduced by 50% during other seasons	60% RDF in the ratio 2-1-0 (July- August), 2-2-2 (September-November), 0-1-1 (December-January) and 0-0-2 (February-April).	300g Biofertilizer consortia	5-10 kg neemcake need to be applied per plant per year. Foliar spray of micronutrients will enhance the growth and productivity.
Papaya	1.8 m x 1.8 m	AMC Enriched FYM @ 5 kg/plant at the time of planting and repeated at 6 months interval @ 2 kg/pl	250 g N + 250 g P_2O_5 + 500 g K_2O per plant/year	60% ER 6 to 8 litres of water/plant /day by placing drippers midway between trunk and skirt line	80 % RDF through fertigation at regular intervals (450 g N /plant)	-	Sub surface drip irrigation gives 10% higher yield over surface drip irrigation. Fertigation gives 9.3% higher yield over soil application of fertilizers
Grapes	3 m x 2m (Seedless varieties)	50 kg /plant, 3 kg of bone meal, 2 kg of castor cake, pongamia cake or neem	300:300:600 kg /ha/year, respectively for seedless cultivars	80% ER (the yield decreases with decrease in ER with one emitter/plant or alternate irrigation)	After April pruning 8-40 days : 1-2-0, 41-75 days : 0-1-1 76-90 days :0-0-1 After October pruning 8-35 days : 1-1-1,		Sandy soils :Salinity– upto 2.5 dS /m Sodium-15-20 m.eq/l Avoid water with EC more than 2 dS/m and cl with more than 3 m eq/l in sandy soils and more than 4 m eq/l in heavy soils, RSC to be less than 2.

Contd.

Crop	Spacing	FYM	Recommended Fertilizers (RDF) (g NPK/ plant/ year)	Drip irrigation Schedule at	Fertigation with water soluble fertilizers	Biofertilizers/ others	Additional care
		cake and 2 kg of super phosphate			36-75 days : 1-0-2 75-90 days :0-0-291-120 days :0-0-1 (Adjust the nutrient needs based on petiole analysis)		
Guava	4m x 4m	25 t/ha	900:600:600g NPK/plant/year	50% ER (10-12 litres/day during flowering to fruit development)	Recommended N and K through water soluble fertilizers and P through soil application		Soil application of 800g $ZnSO_4$/t reeorfoliar spray of 0.5 per cent $ZnSO_4$ and 0.4 per cent boric acid1 0 to14 day sbeforee very flowering, is effective in eliminating the deficiencies.

transport of so-called chemical signals from roots to the shoot *via* the xylem to induce a physiological response (Dodd *et al*., 2015). Further, PRD irrigation method limit vegetative vigour and improve water use efficiency (Kriedmann and Goodwin, 2003)**.** The wetted and dried sides of the root system are alternated with a frequency according to soil drying rate and crop water requirement.

The physiological and morphological alteration of plants under partial root-zone irrigation may bring more benefits to crops than improved water use efficiency where carbon redistribution among organs is crucial to the determination of the quantity and quality of the products (Shaozhongkang and Jianhua Zhang, 2004). Further, soil drying not only limits root water uptake which can (but not always) perturb shoot water status, but also alters transport to shoots to regulate leaf growth and gas exchange. Re-wetting the soil rapidly restores leaf water potential and leaf growth (minutes to hours), but gas exchange recovers more slowly (hours to days), probably mediated by sustained changes in root to shoot phyto-hormonal signaling. Moreover, PRD irrigation can improve crop nutrition and re-wetting dry soil provokes both physical and biological changes which affect soil nutrient availability (Dodd *et al.,* 2015).

Wetting and drying each side of roots are dependent on crops, growing stage, evaporative demands, soil texture and soil water balance (Saeed *et al*., 2008). Yet there is little understanding on the mechanism of PRD effects on crop growth. In PRD, roots sense the soil drying and in wet soil absorb sufficient water to maintain a high water status in shoot (Zegbe and Behboudian., 2008; Liu *et al*., 2006; Ahmadi *et al*., 2010). However, the level of meeting the crop evapotranspiration demand based on the PRD irrigation in a given agro-climatic situation needs to be standardised for a given crop.

Papaya (*Carica papaya* L.,) is a common fruit crop grown in the Southern region. The crop is normally grown under protective irrigated conditions. However, in the recent past owing to scarcity of water for irrigation, following alternate approaches to save the scarce water and bring more area under cultivation assumes significance. Keeping this as a backdrop, a research trial was initiated at ICAR- Indian Institute of Horticultural Research to standardize the partial root zone drying irrigation in papaya (*Carica papaya L.*). The results indicated that although irrigation in papaya meeting 80% replenishment of evaporation even with one emitter per plant resulted in significantly higher number of fruits (54/plant), higher water productivity (23.7 kg/m^3) could be obtained by scheduling the irrigation at 40% ER through shifting of laterals at fortnightly intervals. This also led to a saving of substantial water (1285m^3/ha) resulting in 144.2 % higher water productivity. It is worth to mention that the papaya plants withstood the water stress and functioned normally even when irrigation was scheduled at 40% of ER. Water use efficiency followed a similar trend with scheduling the irrigation at 40% evaporation replenishment through shifting of laterals at fortnightly interval leading to 159.5 % higher water use efficiency (237.4 kg/ha.mm). Dry *et al.* (2000) stated that this increased WUE with PRD is because the well-watered half of the root ensures the maintenance of fruit growth, while vegetative growth is reduced. The ability of roots to absorb nutrients was also improved when the root zone was partially watered and the partial watering was shifted alternately in a horizontal direction or along the vertical soil profile (Han and Kang, 2002). Similar results of 40% higher WUE was recorded by De la Hera *et al*., (2007) in grapes under PRD treatments. Further, Du *et al.*, (2008) concluded that improved WUE, earlier fruit maturity and better quality of table grape without detrimental effects on the fruit yield in arid areas are the advantages of PRD irrigation.

Soil Volume Wetting Irrigation

The restricted volume of the wetted soil under drip irrigation and depth-width dimensions of this volume are of considerable practical importance. The volume of the wetted soil represents the amount of soil water stored in the root zone, its depth dimension should coincide with the depth of the root system while its width dimension should be related to the spacing between the emitters and lines. The parameters which influence the wetted soil volume are the available water holding capacity of the soil and the peak daily crop water use representing specific field conditions. The irrigation interval and the management-allowed deficit are additional parameters which affect the wetted volume and could be changed depending on crop sensitivity as well as water and irrigation equipment accessibility. A truncated ellipsoid is assumed to best represent the geometry of the wetted soil volume under an emitter. The partial soil wetting pattern by micro irrigation requires assessment of the percentage of soil volume that is wetted (Sne Moshe. 2006). Distance between emitter on lateral pipe and distance of lateral pipes from each other should be determined based on the degree of wetted soil diameter by emitters. Duration of irrigation also depends on the fact that at what time after commencement of irrigation, the wetting front reaches depth of plant's root or a multiple of it. Distance of outlets, discharge rate and time of irrigation in drip irrigation have to be determined so that volume of wetted soil is close to volume of plant's root as much as possible. Volume of wetted soil surface and moisture in onion shape depends on different factors including soil texture and layering, soil homogeneity, dripper flow rate, primary moisture of soil, consumption water and land slope. Analyses on the effects of application rate on the water distribution pattern demonstrated that increasing the water application rate allows more water to distribute in horizontal direction, while decreasing the rate allows more water to distribute in vertical direction for a given volume applied (Li, *et al*., 2004).

Keeping this in view, field experiments were conducted to adjudge an optimum soil volume wetting irrigation in papaya along with different plant spacing. The results indicated that narrowing the plant rows drastically reduced the plant height while leaf production affected significantly due to reduction in intra row spacing. The height at first fruiting was significantly lower with a spacing of 1.8 m x 1.5 m (56.4 cm) significantly differing from both 1.5 m x 1.5 m (60.9 cm) or 1.8 m x 1.8 m (66.8 cm). Significantly higher mean fruit yield (42.2 t/ha) was recorded with the spacing of 1.5 m x 1.5m as compared to either 1.8m x 1.5m (23.4 t/ha) or 1.8m x 1.8m (22.1 t/ha). Significantly higher water use efficiency (71.3 kg/ha.mm) was recorded in papaya by following closer spacing of 1.5 m x 1.5 m. Among the interactions, higher papaya yield (48.0 t/ha) was recorded with normal drip irrigation (80% soil volume wetting) under closer spacing (1.5 m x 1.5 m). Further, higher water use efficiency (129 kg/ha.mm) could be obtained by scheduling the irrigation at 30% soil volume wetting especially by planting at 1.5 x 1.5m spacing suggesting its suitability for water scarcity areas.

Sensor based Automation in Irrigation

An automated irrigation system refers to the operation of the system with no or just a minimum of manual intervention beside the surveillance. Almost every system (drip, sprinkler, surface) can be automated with the help of timers, sensors or computers or mechanical appliances. It makes the irrigation process more efficient and workers can concentrate on other important farming tasks. On the other hand, such a system can be expensive and very complex in its design and may need experts to plan and implement it. This automatic irrigation system senses the moisture content of the soil and automatically switches the pump when the power is on. A proper usage of irrigation system is very important because the main reason is the shortage of availability of water due to lack of rain. Further, large amounts of water goes as waste with unplanned use of water. For this reason, use of the automatic plant watering system is very useful in all climatic conditions.

Irrigation systems can also be automated through information on volumetric water content of soil, using dielectric moisture sensors to control actuators and save water, instead of a pre-determined irrigation schedule at a particular time of the day and with a specific duration. An irrigation controller is used to open a solenoid valve and apply water to bedding plants when the volumetric water content of the substrate drops below a set point.

A precision irrigation system which takes advantage of the various phases of plant growth was developed and implemented using the sensor network technology integrated with IOS/Android. The amount of water in the soil was measured via sensors that were placed on certain points of the area to be irrigated. These sensors were placed near the root of the product. Data from sensors was transmitted via Wi-Fi in real-time to a mobile phone based on IOS/Android. In the light of obtained data, the seasonal precision irrigation system was created depending on the amount of water required by the plants at each stage of their crop growth. The required energy of the system was provided by solar power. The system can be controlled by smart phones which increases the usability of the system. When design performance was analyzed, it was observed that some important advantages such as obtaining high efficiency with water, time and energy saving and reducing the workforce were ensured. Five separate laterals were used for the irrigation system. There were valves on each lateral, which realized the opening and closing process depending on the water need. A total of 16 humidity sensors were used in the irrigation system and the data from these sensors was transferred to the IOS/Android server via the programmable controller (PLC). The basic electrical equipment in the irrigation system was monitored and controlled via mobile devices. Control parameters were obtained by comparing the real values and reference values by a closed-loop system and determine the new working status of the irrigation system (Mehmet FatihIsýk *et al*., 2017).

The mobile application is to control the system remotely which allows to monitor the whole system and if there is any problem or passing of water user can switch off the system through this application. The controller uses calibrated, dielectric moisture sensors, interfaced with a datalogger and solenoid valves to measure the moisture content of the substrate every 20 minutes. When the moisture content of the substrate drops below the set-point, the controller opens a solenoid valve which results in irrigation. The moisture content of the substrate is maintained near a constant level as the datalogger is programmed to increase use by only 2–3% during each irrigation. Using this controller with bedding plants, it is possible to maintain distinct levels of moisture for a prolonged period (40 days), regardless of changes in plant size and environmental conditions. The daily average maintained was slightly higher (within 2–3% on any particular day) than the set-point. When the moisture measured and maintained by the dielectric moisture sensors was tested using measurements with another probe placed in the same container, the measurements by both probes was found to be similar, indicating that the controller can indeed maintain the same near the target level. This controller may also have applications in stress physiology, since it allows control over the rate at which drought stress is imposed on plants (Nemali *et al.,* 2006).

CONCLUSION

An integrated approach which involves efficient conservation of rain water and careful utilization of surface and sub surface resources will go a long way for sustainable use of water. Evolving regulated deficit irrigation technologies for different fruit crops and standardisation of fertigation schedules for enhanced water use efficiency is a right step in this direction. Sensor based irrigation technologies with energy of the system provided by solar energy and controlled by smart phones increases the usability of the system.

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