WATER MANAGEMENT IN CITRUS – A REVIEW
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ABSTRACT
Irrigation management is one of the prime concerns of modern citiculture irrespective of water resource availability. A variety of recommendations have emerged world over on irrigation scheduling based on analysis of meteorological parameters, evapo-transpiration, depletion of available water content, soil and leaf water potential. The review of literature has revealed best promising results on irrigation scheduling based on depletion pattern of soil available water content. Various micro-irrigation systems have established their superiority over traditionally used flood irrigation with microjets having little edge over rest of the others. Similarly, fertigation has shown good responses on growth, yield, quality and uniform distribution pattern of applied nutrients within the rootzone compared to band placement involving comparatively localized fertilization. Automated fertigation in citrus orchards is a new concept, which would be the only solitary choice amongst many irrigation monitoring methods in near future.

With increasing demographic pressure, the per capita energy requirement has been mounting year after year to feed the growing population. This has put agriculture under great stress especially from irrigation management point of view, with horticulture crops being no exception. The realisation of nutritional security through increased horticulture production has further magnified the gravity of the problem. The vagaries in climate, uncertain and uneven rainfall pattern has forced the researchers to find ways and means to adopt strategies, which could allow every drop of irrigation water to be used judiciously. India’s annual rainfall on an average is 117 cm with major portion received during July-September. The various available estimates indicated that the maximum amount of exploitable irrigation potential by all types of irrigation is 113.5 million ha. This would be sufficient for 50% of the total cultivable area of the country leaving rest of the 50% area dependent exclusively on rainfed farming. Conjunctive use of rain backed up by in situ conservation and efficient use of irrigation water, offer a promising scope for optimizing water use in areas having water scarcity.

During the last three decades, if area and production trends of Indian citrus industry are critically analysed, there has been no consistent increase in total production with area expansion. The scarcity of irrigation at critical growth stages is one of the major constraints limiting the productivity. This has induced large scale drying of citrus orchards every year due to frequent drought and lower watertable (Dass, 1989).

Flood irrigation has been the most common of all methods of irrigation to citrus orchards, which allows not only heavy leaching of applied nutrients, but sometimes act as predisposing factor for fungal diseases besides consuming huge amount of water for each irrigation. The use of micro-irrigation system is gradually gaining popularity amongst the citrus growers and warrants a thorough stock taking of available literature on this aspect. The moisture conservation techniques like mulching and fertigation are also equally pertinent from water and fertilizer conservation point of view.

1. Irrigation scheduling and water requirement
Various methods of monitoring irrigation and meeting the water requirement have been tried. The water requirement of citrus plants varies with species, season and age governed with different climatic conditions. Plant growth retards below certain critical level of available moisture depending upon soil type, climatic
factor and plant genetic make up (Rajput, 1989). Irrigation at 65% field capacity caused drought injury symptoms, excessive defoliation and less water consumption. Best results were obtained with irrigation at 85% filed capacity. Evapo-transpiration ranged from 3.78 to 4.42 and 1.46 to 1.3 mm/day for 85% and 65% field capacity irrigations respectively (Toledo et al. 1982). Kelin (1983) compared drip irrigation scheduling according to soil water potential to class A pan evaporation in different horticultural crops using a crop factor and concluded that 12 to 23% water could be conserved by using the irrigation scheduling based on soil water potentials. Moreshet et al. (1983) studied the 100% and 40% of soil volume irrigation in ‘Shamouti’ orange and found that partially irrigated plot was 66% of that of the fully irrigated one. Transpiration from the trees of partially irrigated plots was 72% of that of the fully irrigated plot and the evaporation from the soil surface was 58%. Fruit TSS and acid contents were higher in partially irrigated plots. The water use efficiency is the feature of any water management programme, which should aim at enhancing nutrients on one hand and ensure a good quality fruits with sufficient conservation of moisture and advancements made in technically advanced frontline citrus growing countries. These gaps in scientific know how are the precise bases for reviewing the current state of knowledge available on irrigation management in citrus and analyse how best this information would be diverted to benefit Indian Citrus Industry.

The growth of ‘Valencia’ oranges slowed down at 32 cb and 55 cb soil suction at 30 cm depth in light and medium textured soil, respectively (Hilgeman and Hewland, 1955). The preliminary studies on the effect of soil management system on soil moisture in Sweet orange orchard in India was initiated by Randhawa et al. (1960). Stolzy et al. (1963) found that the treatments irrigated at 20 Kpa tensiometer readings were best as compared to calendar scheduling. Hashemi and Gerber (1967) attempted correlation between actual evapotranspiration (AET) and potential evapotranspiration computed with Penman’s model. Koo (1968) advised Florida citrus growers to maintain soil moisture at 55 to 65% of field capacity from bloom the young fruit exceeding 1 inch in diameter. Retiz (1968) estimated the water requirement of citrus as 40-45 inch/year. Richards and Warnke (1968) observed that irrigation at 60 cb and extrapolations to 150 cb resulted in no measured differential response in tree growth and fruit yield of lemon under coastal conditions. Leyden (1977) found that 610 mm irrigation at 0, 200, 300 and 400 liters/tree using drip irrigation system gave the significant difference in total yield and fruit size distribution. Smajstrla et al. (1984) found that greatest yields were obtained using spray-jet trickle irrigation. Yield increases were not linear with volume of rootzone irrigated but ranged from 39% for the drip irrigation treatments which irrigated 5-10% of the area beneath the tree canopy to 64% for 2-spray jet per tree, which irrigated 50.7% of the areas beneath the tree canopy. Marler and Davies (1990) found that more than 90% of root dry weight was within 80 cm of the trunk at the end of first growing season and accordingly the irrigation scheduling should be adopted.

Plessis (1985) obtained the highest yields (190 kg/tree) and the largest average fruit size with irrigation at a crop factor of 0.9 on a 3 day cycle, with this consumption micro-irrigation gave better results. Makhija et al. (1986) worked out water need for 6 year old Kinnow mandarin, which varied from 539 to 1276 mm depending upon the level of irrigation with average consumptive use of water in 2 years as 61.5 cm. Smajstrla et al. (1986) concluded that the tree growth of young ‘Valencia’ orange was greatest when irrigations were scheduled at 20 centibar for no-grass
and 40 centibar for the grass treatments. Autkar et al. (1988) observed that the distribution of active roots of Nagpur mandarin as it can be useful in planning irrigation nutrition, planting density and drainage management. The root depth and radial extent for trees aged 1-4 years was 7.5-8.0 cm deep and 5-12.5 cm respectively and for 10 years old age tree it was 2-3 m and 80-90 cm. Studies on different levels of water stress on yield and quality of lemon tree showed lower yield in most stressed plot. The number of flower/m\(^2\) of canopy was higher in most stressed treatment indicating a relationship between severity of stress and flowering response (Barbera and Carimin, 1988). Mageed et al. (1988) observed that the consumptive use varied from 66.7 cm to 132.5 cm for Kinnow mandarin.

Field experiment with a mature 'Valencia' orange trees showed that the water use pattern over the entire season reached a maximum of 87 lit/day in January. Highest net income was obtained with tensiometer scheduling Plesiss (1985). Plesiss (1989) also demonstrated that 690 liters irrigation when tensiometer reading fell to -50kpa gave the highest net income. Use of tensiometer rather than evaporation pan scheduling could save 2000 m\(^3\) water/ha annually (Plesiss, 1988). Autkar et al. (1989) in study on the effect of Pan evaporation, canopy size and tree age on daily irrigation water requirement of 1-5, 5-8 and above 8 years old Nagpur mandarin trees over 9 months (October-June), found that the water requirement rose with age. Ghadekar et al. (1989) estimated that the consumptive use of Nagpur mandarin by modified Penman equation using 40 years meteorological data air temperature, relative humidity, wind velocity and Solar relation data. Under clean cultivation the water requirement of young, middle age and mature trees was 651.9, 849.0 and 997.3 mm/year respectively. An equation for daily water use was proposed and it can be used for drip irrigation. Comparison of five flood irrigation treatments with daily drip irrigation at 0.475 E\(\text{pan}\) indicated that the drip irrigation gave higher yields as compared to flood irrigated plants, Sanehez et al. (1989). Castel and Buj (1990) observed that mature 'Satsuma' trees grafted on Sour orange rootstocks showed a good response on yield and quality when irrigated with 60% of the estimated ET losses from a class A pan and 80% of the control throughout the year.

Ray et al. (1990) in the studies on the response of young 'Kinnow' mandarin to irrigations scheduled at -0.05, -0.1, -0.2, -0.4 and -0.8 MPa soil water potential 0.8 IW/CPE ratio, and observed that the water use increased as the frequency of irrigation increased with highest bio-mass per plant with irrigation scheduled at -0.05 MPa soil water potential (SWP). The above soil water potential (0.05 M Pa soil water potential using 182.4 cm water/tree/annum) was associated with best tree growth in terms of trunk diameter, plant height, canopy volume, leaf number and shoot growth MPa SWP using 182.4 cm water/tree/annum. Ray and Sharma (1990) studied the effect of irrigation on plant water status and stomatal resistance in young Kinnow mandarin and found that the leaf water potential (LWP) and Relative water content (RWC) declined considerably with reduction in soil moisture in rootzone due to differential irrigation schedules. Reduction in RWC was more conspicuous where soil moisture dropped below 11% LWP measurements in early morning hours and showed a significant curvilinear relationship with soil water status. Leaf stomatal values were lowest in September and highest in January. Irrigation scheduling based on depletion of available water content and open pan evaporation in acid lime proved very good in pre-bearing Nagpur mandarin budded on rough lemon (Shirgure et al., 1998). Shirgure et al. (2000a) observed that the evapotranspiration varied from 213.6 mm to
875.6 mm in various irrigation schedules. The change in soil-moisture distribution in the rootzone of acid lime plants varied from 195.9 mm to 321.3 mm under different irrigation schedules.

2. Irrigation methods

The common methods of applying irrigation water to the citrus orchards are basin, border strip, furrow, sprinkler and drip irrigation. Out of these ring basin is generally followed in early establishment phase of fruit trees. Drip and microjet irrigation has the advantage over surface irrigation methods, being a more uniform and attain complete wetting of the soil surface and better adoptability on "Sloppy terrain."

Faton (1970) observed better tree growth and yield, less weed growth, evaporation and leaching with 16 gallons water applied through drip to each 4 years old lime trees at two weeks interval compared to 320 gallon water under flood irrigation. Fritz (1970) observed that if all applied water is transferred directly to rootzone of plants could save 20-50 % water depending on soil and climate. Comparison of drip irrigation with the basin by Raciti and Sckderi (1977, 1978) showed that the fruits under drip system were more acidic and possessed lower maturity ratio. Ronday et al. (1977) observed better tree growth and less water consumption in Valencia orange under drip irrigation in sandy soil. Simpson (1978) found that there is a shift from furrow irrigation and over head sprinkler irrigation systems to under tree systems like microjets. Trickle irrigation on young orange trees used 5400 liters of water compared to 23400 liters of water per tree for dragline (Stack et al., 1978).

Raciti and Barbargallo (1982) observed that the yield of lemon was more with localized irrigation amounting to 227.23 q/h and 213.2 q/h with basin irrigation. Ozsan et al. (1983) on comparison furrow, under tree, over tree and drip irrigation in lemons observed that the amount of water applied were greatest (1286 mm) with under tree method and least (207 mm) with drip irrigation system. Yield was higher with over tree sprinkling followed by furrow with higher water use efficiency under drip irrigation. Cevik and Yazar (1985) demonstrated that a new irrigation system i.e. Bubbler irrigation for the orchards, observed that under tree sprinkling and drip irrigation had the best pomological effects. Amounts of water applied per tree for over sprinkling, under sprinkling and drip irrigation were 22.01, 17.04 and 10.33 m³/season. Except the higher cost, the advantages include saving in labour, water and power, better orchard uniformity and immediate response to crop need, better soil-water relationships, rooting environment and better yield and quality (Pyle, 1985).

Drip irrigation and under tree sprinkling produced the highest yield with the least water requirements. The application rate for drip irrigation of 4 years old lemon trees was 7400 m³/ha annually (Tashbêkov et al., 1986). Capra and Nicosia (1987) concluded that the rates of water application affects the rate of growth of fruit diameter. Increased tree growth and yield were recorded in young Valencia orange under drip irrigation method with emitter placed at distance of 1 meter from the trunk (Azzena et al., 1988). Greive (1988) was of the opinion that under tree micro-sprinklers increased yield by 12% and reduced water application by 9.3% compared to conventional full ground cover. Interligolo and Raciti (1989) demonstrated that water saving with sub-surface irrigation was 32% over the traditional basin irrigation. The yield was higher but fruit quality was not much different. Marler and Davies (1989) found that growth was not affected by pattern of irrigation which suggested that 90% emitters are enough for root system for growth of young Hamlin trees.

Zeki and Parsons (1989) found that fruit size
and tree canopy area were 9 to 20% greater in the overhead sprinkler treatments.

Rumayor et al. (1991) observed that higher yield with sprinkler irrigated trees and smaller fruits under flood irrigation. Smajstrala (1993) researched on micro-irrigation for citrus production in Florida. Gangwar et al. (1997) studied the economics of investment on adoption of drip irrigation system in Nagpur mandarin orchards in Central India and concluded that the drip irrigation system is technically feasible and economically viable with Benefit to Cost ratio as 2.07. Shirgure et al. (2000 b) a good response of dripper 8 liters per hour microjet 300°, microjet 180° and basin irrigation method on water use and growth of acid lime and found that microjet 300° recorded higher growth than rest of the systems. The efficacy of these micro-irrigation systems and basin irrigation were very pronounce on fruit quality and soil fertility changes in acid lime (Shirgure et al., 2000 c).

3. Fertigation

Fertigation is a technique of application of liquid or water soluble solid fertilizer along with irrigation through the drip irrigation to the plants. It has many advantages like increasing fertilizer-use efficiency, ensuring the supply of water and nutrients, labour saving and improvement in yield and quality. It is a very new-under Indian conditions especially with citrus but becoming popular along with an adoption of drip irrigation system. The research related to injection of fertilizers through the drip irrigation systems was started by Smith et al. (1979). Koo (1981) appraised the potential advantages of micro-irrigation systems and its usefulness to fertigation. Bielorai et al. (1984) advocated the use of fertigation technology in citrus, which resulted in higher production and good quality Shamouti oranges. They also compared N fertigation at 100, 170 and 310 Kg/ha with broadcast application at 170 kg/ha through irrigation system. The average yield for 4 years were observed 62, 73 and 82 Mg/ha with 100, 170 and 310 kg N/ha, through fertigation. Koo and Smjstrala (1984) observed that partial fertigation of N and K resulted in lower N contents of leaves with higher TSS and acid concentration in juice and yield remained unaffected in Valencia orange. Haynes (1985) discussed the principles of fertilizer use for trickle irrigated crops. Haynes (1988) found that growth and yields were greatest at the low rate of N applied as fertigation or as a combination of broadcast plus fertigation.

Fouche and Bester (1987) in the studies on fertigation with a soluble fertilizer 'Triosol' (3:1:5) + 350 gm urea by broadcast, fertigation of N and K with broadcast of single super phosphate and NPK through broadcast. It was observed that highest yield with fertigation of NPK through Triosol or by complete broadcasting of NPK fertilizers. No significant differences were observed in fruit size, acidity, per cent juice content and TSS among treatments. Beridze (1990) obtained highest yield of 6.6 tons/ha from trees fertilized with basal dressing + 250 kg peat/tree as a mulch + FYM at 25 t/ha. Ferguson (1990) showed low to deficient concentrations of N, K, Mn and Zn with both N treatments involving 0.66 N, 1.32 lbN/ha in two year old Citrus reticulata x C. paradisi cv. Sunburst. Zekri and Parsons (1990) observed that inorganic forms (NO3 and SO4) were ineffective in evaluating micro element levels in oranges. But, chelated sources of Fe, Mn, Zn and Cu were very effective and their rates of application were more comparable with rates especially when applied through foliar applications. Neilsen et al. (1993) observed that fertigation with calcium ammonium nitrate showed increased vigour and leaf Ca concentration, but decreased leaf Mg and Mn compared to trees fertilized with urea or ammonium nitrate (NH4NO3) in apple trees.
Fertigation with P increased early tree vigour, leaf and fruit P concentration and decreased leaf Mn.

In a lysimetric study Syveotsen and Smith (1996) on nitrogen uptake efficiency and leaching losses, it was observed that average N uptake efficiency decreased with increased N application rates, overall canopy volume and leaf N concentration increased with N rate, but there was no effect of N rate on fibrous root dry weight. Richard et al., (1996) in a trial on peach orchard with banded fertilizer, low fertigation and high fertigation under non-irrigated, drip irrigated and micro-sprinkler irrigated conditions observed that in the first 5 years of the experimentation fertigation did not provide a significant yield advantage over banded application besides adding to the cost of the fertigation equipment and higher labour requirement. A very little work was done on fertigation in India. The fertigation research in citrus is a recent origin, initiated during 1995 at NRC for Citrus, Nagpur using acid lime as test crop. Effect of differential doses of nitrogen fertigation in comparison with band placement of fertilizer application on leaf nutrients, plant growth and fruit quality of acid lime during pre-bearing stage showed that the percent increase in plant height, stock girth and canopy volume was more with 100 % N fertigation followed by 80 % N of recommended dose in acid lime (Shirgure et al.,1998). The effect of N fertigation on soil and leaf nutrient build-up and fruit quality of acid lime was noted very distinct (Shirgure et al.,1999).

4. Future

Following future strategies are suggested to transform water management research in citrus into a more meaningful and quality production oriented coupled with prolonged orchard longevity.

- Evolvement of an efficient irrigation scheduling for citrus cultivars as per agroecological conditions
- Development of data base comparison on scheduling using tensiometers of various depths, neutron moisture probe, climatological approach like modified Penman equation and water balance approach.
- Use of canopy temperature and leaf water potential as an aid to irrigation management.
- Studies on infiltration rates, water distribution and retention parameters with soil physico-chemical properties in relation to long term use of conventional irrigation methods versus modern micro-irrigation systems.
- Evolvement of suitable micro-irrigation designs to suit the growth habits of citrus cultivars especially with reference to canopy area.
- Relationship between water stress and flowering on one hand and water stress and plant growth on the other hand, which in turn needs to be related to soil characteristics.
- Comprehensive research on fertigation response in relation to soil moisture and fertility distribution pattern.
- In depth study on comparison on use of organic (grass, straws, leaf litter and trashes) versus synthetic (polythene sheets) mulches as an alternative moisture conservation strategy.

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