Research Article

Irrigation Scheduling and Fertigation in Citrus Fruit Crops

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Abstract

Water is a limiting resource in the fruit production. The scarcity of water is pervasive on the earth sphere across all plant growing realm in various plant biomasses. Judicious use of water and nutrients is very essential to achieve sustainable fruit production. Irrigation scheduling and fertigation give many advantages to perennial citrus fruit crops such as higher use efficiency of water and fertilizer, minimum losses of nutrients due to leaching, supplying nutrients directly to root zone in available forms, control of nutrient concentration in soil solution and saving in application cost. Currently, these practices are being used in citrus fruit crops globally. Thus, irrigation scheduling and fertigation becomes prerogative for increasing the yield of most of the crops. In this paper, the literatures pertaining to the different aspects of irrigation scheduling and fertigation in citrus fruit crops are reviewed.

Keywords: Irrigation Scheduling, Fertigation, Citrus Fruit Crops, Growth, Leaf Nutrient

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Introduction

Citrus species are most widely cultivated fruit crops in the world. These fruit crops are grown in about 140 countries across the globe. The genus Citrus includes more than 162 species belonging to the family Rutaceae and sub family Aurantoidae. These are the third largest grown fruit crops after mango and banana in India. In the country citrus fruits are growing in Andhra Pradesh, Maharashtra, Punjab, Madhya Pradesh and Gujarat. Commercially, citrus fruit crops are grown over 1024000 hectare of the total area. The total citrus fruit production of the country is 12.253 million tonners, in which 40.52 per cent share relates to mandarin, 26.29 per cent to sweet oranges, 23.47 per cent to lime and lemon and 9.72 per cent to other citrus fruit crops [1]. These are economically important tropical and sub-tropical fruits which have juicy, pleasant flavor, and sour-sweet taste. The fruits are delicious, refreshing, thirst quenching and good source of vitamins, sugars, minerals etc.

Water is a limiting resource in the fruit production. The scarcity of water is pervasive on the earth sphere across all plant growing realm in various plant biomasses. It is the main constraint for fruit production in state such as Rajasthan, some parts of Gujarat, Utter Pradesh, Maharashtra and Madhya Pradesh which comes under dark zone. The ground water resource is getting limited day by day owing to excessive use of aquifer without much concern for its recouperation. Any water saving technique is certain to put growth and survival to plants. The use of micro/drip irrigation system is expected to result in water saving, and likely to hasten plant growth. Hence, it would be attempted to observe the growth and development of citrus fruit crops (**Figure 1**) under the influence of different volumes of water.

Irrigation scheduling

Irrigation scheduling is the decision of when and how much water to apply to a plant. The purpose of irrigation scheduling is to maximize irrigation efficiency by applying the exact amount of water needed to replenish the soil moisture to the desired level. Determination of the frequency and amount of water is the one of the major challenge to the orchardist [2, 3]. Irrigation scheduling is very essential in fruit crops hence, excessive application of water may cause adverse effects such as leaching of nutrient, water logging, soil and water salinity, pests, and diseases whereas, inadequate water may reduce growth, yield and quality of fruit crops. It has many advantages such as minimize crop water stress and maximize yields, saving in time, labour, water and energy, maximum use of soil moisture storage, minimizes fertilizer and water leaching, it increases net returns by increasing crop yields and crop quality and it minimizes water-logging problems by reducing the drainage requirements.

Figure 1 Drip irrigation in different citrus fruit crops

Calculation of water (ETc) for irrigation scheduling

Based on pan evaporation reading, the volume of water shall be calculated. Suppose, pan evaporation reading is 10 mm, then volume of water has been calculated as under.

$$ETc = ETo \times Kc \times A - Re$$

Where, ETc = Volume of water required in litre per day; ETo = Reference evapotranspiration
Ep = Pan evaporation which has been taken as 10 mm; Kp =Pan co-efficient 0.7 [4] for class A pan evaporimeter.

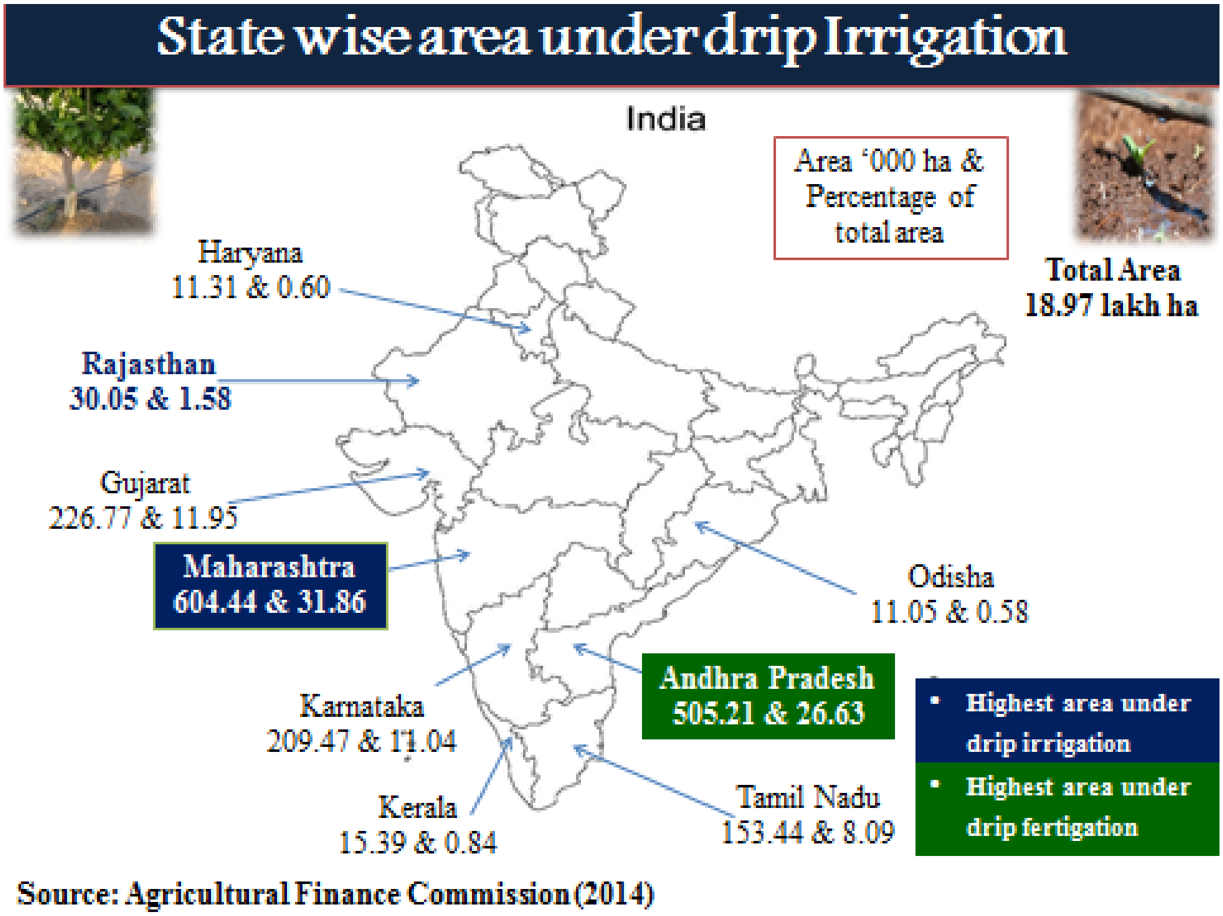
$ETo = Ep \times Kp$
$= 10 \times 0.7 = 7$ mm

Kc = Crop co-efficient which is 0.60 (Kc considering Kc values to be 0.50 in month January, 0.55 in month November to December and February to March, 0.60 in month April to May and October, 0.65 in month June and September, 0.70 in month of July and August,
A = Average canopy area, which is 0.8 m^2 in the plants in experimental field.
Re = Effective rainfall 0.00 mm

$ETc = 7 \times 0.6 = 4.2$
$WR = 4.2 \times 0.8$
$= 3.36$ litres per day

Likewise, for day to day changing pan evaporation, volume of water (ETc) shall be calculated for the propose of experiment.

The combination between the two costly inputs like water apply through irrigation schedule and fertilizer apply through fertigation determines the sustainability of high crop productivity and quality produce. It was proved by many researchers that amount of drip irrigation in citrus provide better plant growth and higher production of quality fruits in addition to other economic benefits [5-7].



Fertigation

The concept of drip fertigation is first coined by Symcha Blass (Israel) in the year 1960. Fertigation - a technique of application of fertilizers along with irrigation water provides an excellent opportunity to maximize yield and minimize ground water pollution caused by leaching. Drip fertigation is the most efficient technology of irrigation to supply precise amounts of water and fertilizer, directly into root zone at right time, matching with the consumptive water demand of plant for optimum growth, higher yield and quality of produce. In drip fertigation, nutrient use efficiency could be as high as 90 per cent as compared to 40-60 per cent in conventional methods, whereas it also reduces leaching losses of fertilizers [8].

Fertigation offers benefits such as:

- Improves availability of nutrients and their uptake by the plants
- Less fertilizer required
- Improved fertilizer use efficiency
- Saving in time, labour and energy
- Retarded weed growth
- Enhanced plant growth and yield potential
- Minimized pollution of soil
- Prevention soil erosion

Characteristics of fertilizers suitable for fertigation (**Table 1**)

- High nutrient content readily available to plants
- Fully soluble at field temperature conditions
- Fast dissolution in irrigation water.
- No clogging of filters and emitters
- Low content of insoluble (<0.02%)
- Compatible with other fertilizers
- Minimal interaction with irrigation water

Table 1 Fertilizers Suitable for Fertigation

Fertilizer	N-P-K content (%)
Urea	46-0-0
Ammonium Nitrate	34-0-0
Ammonium Sulphate	21-0-0
Calcium Nitrate	16-0-0
Magnesium Nitrate	11-0-0
Urea Ammonium Nitrate	32-0-0
Potassium Nitrate	13-0-46
MAP	12-61-0
Potassium Chloride	0-0-60
Potassium Thiosulphate	0-0-25
MKP	0-52-34
Phosphoric acid	0-52-0
NPK	18-18-18,19-19-19, 20-20-20
Potassium Sulphate	0-0-50

Methods of fertigation

Modern fertigation should be able to regulate: quantity of fertilizer, duration of applications and proportion of fertilizers. Four systems are commonly used:

Continuous application

Fertilizers are applied at a regular rate with irrigation water. The total quantity is injected regardless of water release rate.

Three-stage application

Irrigation starts without fertilizers. Application of fertilizer begins when the soil is wet. Fertilizer injection cuts out before the irrigation cycle is completed. Remainder of the irrigation cycle allows the fertilizer to be flushed out of the system.

Proportional application

The injection rate is proportional to the water discharge rate, e.g. one litre of solution to 1000 litres of irrigation water. This method has the advantage of being extremely simple and allows for increased fertigation during period of high water demand when most nutrients are required.

Quantitative application

In this system, nutrient solution is applied in a calculated quantity to each irrigation block, e.g. 10 litres to block A, 20 litres to block B. This method is suited to automation and allows the placement of the nutrients to be accurately controlled [9].

Automation drip fertigation system

FertiKit3G™

- The FertiKit3G™ is a highly versatile and precise dosing system suitable for an unrivaled range of irrigation system capacities. Covers all applications ranging from open fields to intensive horticulture [10].
- Requiring a minimal investment, the FertiKit3G™.
- A CE-compliant modular system, is the industry's most cost-effective dosing system, whether used for small or large-scale applications.
- Flexible: Works with a very wide range of dosing
- Channel flow rates up to 6 units of 50 to 1000 l/hr.
- Scalable: For systems from 5 m3/h to 700 m3/h capacity and pressures up to 8.0 bar.
- Cost-effective: Requires minimal investment

- With rapid return on investment (ROI).
- Do not require a booster pump (**Figure 2**).

Figure 2 Drip Fertigation System

Effect of Irrigation Schedule and Fertigation on Plant Growth

Irrigation scheduling and fertigation affect plant growth and development in terms of height [4], stem girth [11], canopy volume [12] in citrus fruit crops. Goramnagar *et al.* (2017) [11] reported the highest plant height (3.86 m) and plant spread (4.41) in 100 per cent irrigation of Evp whereas, highest plant height and plant spread observed in 100 per cent RDF of fertigation level in lime. The application of fertigation with NPK at the dose of 120 per cent RDF (600:288:288g/plant/year) gave the highest increase in plant height (87.69 cm), stem girth (6.23 cm), canopy volume (70.22 cm^3) of Kinnow tree under high density planting condition. The raise in plant growth parameters might be due to balance nutrients in rootzone which create better environment for growth of plant. Furthermore, there was a regular supply of nutrients in fertigation as the fertilizers were useful in split doses during the whole growth period of the plants, which may encourage the plant in gathering the necessities of nutrients during the critical period of growth [13]. Kumar *et al.* (2013) [4] observed that individual effect of regime on plant height (0.61 m), stem girth (6.08 cm), plant canopy volume (0.115 m3), were found maximum with application of 1.0 volume of water through drip and individual effect of fertigation on plant height (0.46 m), stem girth (5.34 cm) and plant canopy (0.07 m3) were found maximum under 125 per cent RDF. In case of interaction effect of water regime and fertigation maximum growth in terms of plant height (0.75 m) and plant canopy volume (0.163 m3) were found maximum at 1.0 volume of water through drip along with fertigation of 125 per cent RDF in sweet orange cv. mosambi.

Effect of Irrigation Schedule and Fertigation on Fruit Yield

The influence of irrigation scheduling and fertigation on fruit yields of citrus trees has been studied by many researchers with differing findings. It was observed that maximum number of fruits, maximum fruit weight and fruit diameter was found with 0.8 volume (V) of irrigation and 80 per cent of RDF through fertigation in kinnow mandarin. The maximum number of fruits with 0.8 V irrigation may be due to constant and adequate availability of wetness in plant rhizosphere throughout the fruit developmental stages which finally improved the fruit retention power of plant [14]. Goramnagar *et al.* (2017) [15] reported highest fruits (676.6) produced under 80 per cent irrigation of Evp, whereas, higher number of fruits were produced under100 per cent RDF through fertigation in acid lime. Throughout the *Hasta Bahar* the water requirement for the growth and metabolic action was less due to the low total evaporation for the duration of the October to February, which may have support the higher number of fruits due to less evapotranspiration demand so, lesser levels of irrigation have produce extra number of fruits. The number of fruits per plant was maximum it may be due to use of higher levels of fertilizers but, the magnitude of increase in number was comparatively more in in-between levels of irrigation which were closer to higher levels. Supplementary, the higher level of irrigation produces more vegetative growth development as compared to reproductive growth and vice a versa.

Effect of Irrigation Schedule and Fertigation on Fruit Quality

It was observed that maximum TSS percentage was recorded under 80 per cent of ETc with 700 g potassium per plant per year, while maximum juice content was observed at 100 per cent ETc with 800 g potassium/plant/year also. It indicated that raise in the potassium content enhanced the yield and quality but the juice content was more when plants were supplied with 100 per cent ETc, since enough water supply leads to rise in the juice content of fruits [17]. It was reported that maximum juice content under individual irrigation level 100 per cent and 100 per cent fertigation level. Significantly higher TSS was noticed in the individual irrigation level 80 per cent and significantly maximum TSS (7.40° Brix) was noticed in the individual fertigation level 100 per cent in acid lime [15]. Kuchanwar *et al.* (2017) [18] observed that the highest TSS and lowest acidity value was recorded in fertigation with 120 per cent of RDF (recommended dose of fertilizer). The highest ascorbic acid was recorded in fertigation with 160 per cent of RDF and lowest ascorbic acid was found in fertigation with 80 per cent of RDF in Nagpur mandarin. The quality parameters in terms of highest TSS, juice per cent, lowest acidity and TSS-acidity ratio under fertigation with 85 per cent of RDF, was recorded in Nagpur mandarin [19].

Effect of irrigation scheduling and fertigation on leaf and soil nutrient status

It was reported that highest leaf K content was found in case 100 per cent ETc with 800 g K/plant/year (1.33%) in kinnow [16]. Karuna *et al.* (2017) [20] was observed highest leaf nitrogen content (2.28 %), Zn (29.30 ppm) and Mn (70.76 ppm) in 100 per cent RDF of in basal with drip irrigation. The fertigation treatment 60 per cent RDF recorded the highest concentration of micronutrients, Fe (270.10 ppm) and B (45.67 ppm). The Cu content in leaves was found highest (8.12 ppm) under 80 per cent RDF in kinnow. The improved micro-nutrient concentration with higher dose of fertigation treatments may be attributed due to effect of higher and frequent supply of NPK fertigation during the growing season resulted in maintaining the sufficient moisture and nutrient content in the soil [21, 22]. Kuchanwar *et al.* (2017) [18] observed fertigation with 160 per cent of RDF showed highest total leaf N, P, K, Cu and Fe content during fruit development stage (after 6 months of fertigation) in Nagpur mandarin. It was reported that the highest Leaf N, P and K content with irrigation at 80 per cent ER, in Nagpur mandarin [12]. At the time of final leaf nutrient analysis, it was observed that highest concentration of macronutrients (N, P and K) and micronutrients (Fe, Mn, Cu, and Zn) was reported in fertigation in Nagpur mandarin [23].

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