HortFlora Research Spectrum www.hortflorajournal.com
Vol. 5, Issue 4; 325-330 (December 2016) **ISSN: 2250-2823**

OPTIMIZATION OF IRRIGATION STRATEGIES FOR HIGHER BIOMASS AND FRUIT PRODUCTION IN KINNOW MANDARIN OF LOWER HIMALAYA

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ABSTRACT : The experiment on Kinnow mandarin was laid out in split-plot design with four replications. The treatments comprised of four frequencies of irrigation based on net CPE (CPE-RF) *i.e.* at I_1 = 80 mm, I_2 = 120 mm, I_3 = 160 mm and I_4 = 240 mm in the main plots and two types of organic mulches *viz.* M_1 = Sal (*Shorea robusta*) and M_2 = Lantana (*Lantana camara*) leaves in addition to control (without mulch) in the sub-plots. The tree volume, biomass production, carbon sequestration, fruit yield and physico-chemical properties of Kinnow mandarin were improved significantly with irrigation treatments in order of $I_1 > I_2 > I_3 > I_4$ and mulch did not influenced significantly. The tree volume of Kinnow was recorded maximum (78.94 m^3) with I_1 treatment as 67.5, 26.71 and 12.56 per cent more over I_4 , I_3 and I_2 treatments of irrigation, respectively, which was positively correlated with carbon storage, carbon sequestration and fruit yield in the tree. The highest carbon stock of Kinnow (30.0 Mg/ha) followed by 28.7, 27.4 and 25.2 Mg/ha under different irrigation frequencies, respectively. Maximum fruit yield was recorded (83.30 kg/tree) with I_1 treatment was 76.56, 27.62 and 11.95 per cent more over I4, I3 and I2 treatments, respectively. Kinnow fruit plants raised with M_1 treatment produced 4.94 and 16.02 per cent more fruits than M_2 and M_3 treatment, respectively besides improving the microclimate. The study indicates that irrigation and mulching have positive response on Kinnow mandarin in Doon Valley. Therefore, 75 m^3 water per plant with mulch is optimum is recommended for carbon dioxide mitigation and fruit production in Kinnow mandarin in sandy loam soils.

Keywords : *Fruit production, drip irrigation, pan evaporation, mulch, carbon stocks, CO_2 mitigation, fruit quality.*

Kinnow mandarin is an interspecific hybrid between king of orange (*Citrus nobilis*) and willow leaf (*Citrus deliciosa*) evolved by Dr. H. B. Frost at California Research Station (U. S. A.) in 1915 and was released in 1935 for cultivation, which was introduced in 1959 at Abohar (Punjab). It has been emerged as an important fruit crop in our country. It holds the second position after mango with respect to production and adoptability of various fruits in Doon Valley of Uttarakhand. Kinnow mandarin is commercially being grown by farmers in the region because it thrives well and tolerates pool frost which is a general phenomenon takes place once in 4-5 years among subtropical fruit species. The fruit yield of kinnow mandarin depends upon many factors such as climate, location, rootstock, soil health, water quality, insect's pests and diseases etc. However, inadequate rooting system with vestigial root hairs in kinnow mandarin limits the absorption of water and high transpiration rate due to greater stomatal density. Therefore, inadequate soil moisture regimes may lead the plant to sub-optimal moisture stress, which would invariably affect the yield and quality of fruits. The water requirement of citrus fruits depends on many factors like species, age, canopy spread, plant vigour, soil health, etc. Sandy loam soils of lower Himalaya have very poor water holding capacity, which affects fruit production of kinnow mandarin and can be enhanced substantially through maintenance of adequate soil moisture in the root zone during fruit setting to fruit developmental stage (Koo and McCornak, 7). The water requirement of citrus was estimated as 40-45 inch per year (Reitz, 23). Toledo (29) obtained best results with irrigation at 85% field capacity, while irrigation at 65% field capacity brought about drought injury symptoms, excessive defoliation and less water uptake. The highest yield and the largest fruit size of Valencia orange were obtained with irrigation at a crop factor of 0.9 on a 3-day cycle (Plessis, 13; (Lal *et al.,* 10; Singh *et al.,* 24; Sharma *et al.,* 25).

Article's History:
Received : 12-11-2016 *Accepted : 14-12-2016*

Fruit trees are known for harvesting atmospheric CO_2 for food manufacturing which is otherwise contributing to global warming. There is sharp rise in CO_2 concentration (405 ppm) which is 29.8% higher

CO_2 concentration in 2016 as compared to 312 ppm (0.0312%) in 1950 in the atmosphere, which increased temperature by 1.5°C globally (IPCC, 2016). CO_2 concentration has to be kept below pre-Industrial revolution (280 pp) and temperature. In addition to biomass production by sequestering atmospheric CO_2 for mitigation of climate change and global warming, fruit trees are also known for fruit yield and quality (Rathore *et al.,* 22), which offers opportunity to work upon fruit trees for evaluating capacity for absorbing atmospheric CO_2 in the form of biomass productions. Information of CO_2 sequestering and biomass production is presently lacking in the horticulture sector. Fruit tree orchards have received attention in recent years by virtue of their potential to act as carbon pools (Phani Kumar *et al.*, 12; and Verma *et al.,* 28) besides production and nutritional security.

Doon Valley, although, receives about 1600 mm monsoon rains per year but rains during March to mid June are scanty, unpredictable and meager. In such situation, application of mulches on soil surface may be one option. Mulches play an important role in reducing soil erosion, improving soil structure, organic matter content, microbial flora and better soil aeration, regulating soil temperature, conserving moisture in-situ (Adams, 1; Krugtov, 8; Negi *et al.,* 11, Rathore, *et al.*, 17; Bajwa *et al.,* 2; Rao *et al.,* 15, Verma *et al.,* 29). Thus, standardization of mulching practice with irrigation scheduling appears a viable option for sustainable production of kinnow fruits and mitigating effect of climate change. Hence the study was undertaken as optimization of irrigation frequencies and organic mulches for higher biomass and fruit production in kinnow mandarin.

MATERIALS AND METHODS

The experiment was conducted during 1997 to 2010 on 3 years old uniformly grown kinnow plants at ICAR-IISWC Research Farm, Selakui, Dehradun, Uttarakhand, (India). The kinnow plants established during July 1995 at 5m $\times$ 5m spacing. The surface soil of the experimental field (0-30 cm) is sandy-loam in texture, slightly acidic in reaction (pH 6.0) with medium organic carbon (0.61%), poor total N (0.064%), medium available P_2O_5 (45.97 kg ha^{-1}) and rich in available K_2O (236.80 kg ha^{-1}). Soil water content at field capacity and permanent wilting point ranged between 24.7-22.2 and 7.4 – 6.6 per cent, respectively in different soil horizons within 0-90 cm depth, whereas, bulk density of soil varied between 1.10-1.14 mg m^{-3}.

The experiment was laid out in split-plot design with four replications. The treatments comprised of four frequencies of irrigation based on net CPE (CPE-RF) *i.e.* at I_1 = 80 mm, I_2 = 120 mm, I_3 =160 mm and I_4 = 240 mm in the main plots and two types of organic mulches *viz.* M_1 = Sal (*Shorea robusta*) and M_2 = Lantana (*Lantana camara*) leaves in addition to control (without mulch) in the sub-plots. Three plants were kept as one experimental unit. Irrigation treatments were imposed through drip system of irrigation. Each plant having four drippers installed in four directions and the discharge rate of each dripper was about 8 litres per hour at 2 kg pressure. Soil-moisture content upto 90 cm soil depth was considered for irrigation as advocated by Bielorai *et al.* (3) for citrus species and quantity of water corresponding to deficit was added to the plants at the time of each irrigation (Kumar *et al.,*9). Mulching was done @ 1 kg dry leaves per m^2 in a circular basin of 1.0 m radius on mid March during experimentation period. The NPK contents in the leaves of Sal and Lantana were determined which was found 1.894, 0.197, 0.54 and 3.776, 0.270, 1.29 per cent, respectively. Recommended dose of N, P., K and micronutrients in the three splits were applied to the plant basins according to their age of tree during experimentation period.

Observations were recorded on tree volume, fruit yield, carbon storage and CO_2 mitigation. Fruit quality parameters were determined according to procedures described by Ranganna (14) and the total soluble solids content of fruit were recorded with the help of a hand refract meter calibrated in °Brix at 20°C. Carbon stock in different part of Kinnow tree (roots, stems, twigs, leaves, fruits) was obtained by multiplying the dry weights of plant by their average carbon concentration present in them. Carbon was assumed to constitute 50% of the ash-free dry mass. Ash content was determined by igniting 1.0 g of powdered sample at 550°C for 6 h in muffle furnace and is expressed in Mg ha^{-1}. Statistical analysis was done for pooled data over the years for different parameters. The mean effect of treatments were compared at $P< 0.05$ level of significance (Gomez and Gomez, 4). The uniform training, cultural and plant protection practices were followed.

RESULTS AND DISCUSSION

Carbon stocks and CO_2 mitigation

Correlation coefficient between tree volume and carbon stocks of kinnow was (rr^2 = 0.94 and 0.92) as influenced by irrigation frequency and mulching respectively (Fig. 1). Carbon stock (wood + fruit + root + litter) was increased with increase tree volume and frequency of irrigation. The highest carbon stock of Kinnow (30.0 Mg/ha) followed by 28.7, 27.4 and 25.2 Mg/ha among different irrigation frequencies, respectively. However, carbon stock ranged from 28.2 to 27.0 under various mulch treatments showed non-significant effect. Carbon stock was positively correlated with CO_2 absorption from atmosphere. Maximum atmospheric carbon dioxide mitigation was recorded at 80 mm net CPE which was able to absorbed 110 Mg/ha atmospheric CO_2 followed by 105.3, 100.6 and 92.3 Mg/ha in other irrigation treatments. The highest carbon fixation in the plant depends on tree volume, irrigation, manuring, which varies from 103.4 to 98.8 Mg/ha under mulching. Carbon storage / CO_2 mitigation was maximum in kinnow plant irrigated at 80 mm net CPE because favourable moisture in root zone have absorbed more moisture along with nutrients and attained more tree volume, which might have absorbed more CO_2 for photosynthesis, more nutrient availability and vigour of the plants. Carbon stock refers to the absolute quantity of C held at the time of inventory (Takimoto *et al.,* 29). Large C stock does not necessarily mean a large C sequestration potential. The results are further in agreement with the findings of Kanime *et al.* (6) who reported that mango in tarai region (India) yielded 1.43 Mg C ha^{-1} yr^{-1}. Carbon absorption by plants is directly related to biomass production in different components (Verma *et al.*, 28 and Rathore *et al.*, 22). Soil C is currently not considered to be tradable. However, data revealed that plant biomass contained less amount of carbon stock as compared to soils. IPCC (5) also reported that globally carbon stocks in soil exceed carbon stocks in vegetation by a factor of five. Therefore, soil C is important when the potential for absorption for long-term storage is considered (Takimoto *et al.,* 26).

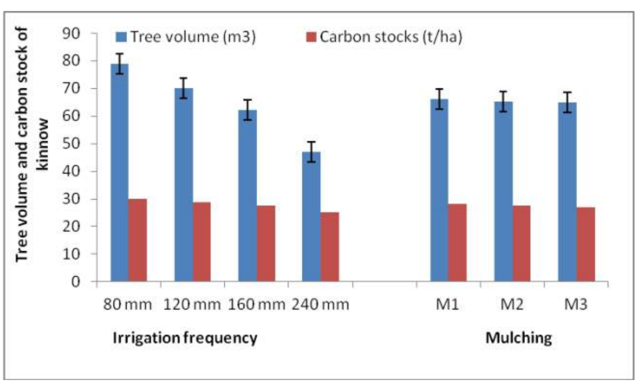

Fig. 1 : Tree volume, carbon stocks and CO_2 mitigation by kinnow under different irrigation frequency and mulching.

Fruit yield and attributes

Correlation coefficient between tree volume and fruit yield of kinnow was (r^2 = 0.95 and 0.90) by irrigation frequency and mulching, respectively (Fig. 2). Fruit yield increased with increase in frequency of irrigation. The highest yield of Kinnow was obtained in the plants irrigated at 80 mm net CPE, which was 76.58, 27.61 and 11.96% more than plants irrigated at 240 mm net CPE, 160 mm net CPE and 120 mm net CPE, respectively. Similarly, Kinnow plant irrigation at 80 mm net CPE attained maximum tree volumes (78.94 m^3), which was 67.5, 26.71 and 12.56% higher than at 240 mm net CPE, 160 mm net CPE and 120 mm net CPE, respectively. However, kinnow plants mulched with Sal leaves exhibited comparatively better plant growth than Lantana mulch and control but were non-significant. The highest fruit yield was recorded in the Kinnow plant 80 mm net CPE because of more water use (75 m^3 /pant) over other treatments which might have reduced flower and fruit drop. It may also be due favorable moisture regime in the root zone at time of flowering and fruit setting during spring-summer season which might have strengthened the abscission zone at the attachment between the flower/fruit and the twig and resulted in better fruit retention and development of fruit (Lal *et al.,* 10; Singh *et al.,* 24). (Sharma *et al.,* 25). Rao *et al.* (16) reported that large tree canopy harvest more atmospheric carbon dioxide for photosynthesis than lesser canopy tree because of high chlorophyll in the leaves. Moisture conservation is positively correlated with tree canopy (Rathore *et al.,* 20 and 21) which indicates that more moisture conservation under the larger canopy tree than lesser canopy tree. Application of mulch slightly reduced plant water use than those without mulch. Sal mulch was

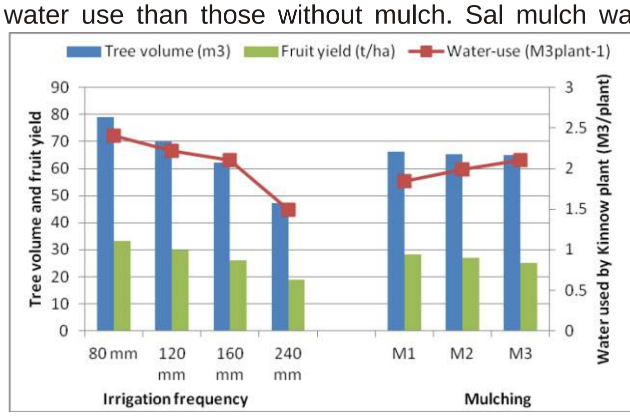

Fig.2 : Tree volume, fruit yield and water use of kinnow under different irrigation frequency and mulching.

found comparatively better than Lantana mulch in reducing the plant water use. Kinnow plants mulched with M_1 treatment recorded lower water use by 7.6 and 13.2 per cent than M_2 and M_3 treatments of mulches, respectively. Mulches reduced atmospheric evaporatibility by retarding solar radiation and wind velocity on soil surface and by increasing resistance to vapour transfer from soil surface to the atmosphere. Rao and Pathak (15) reported similar results in Aonla.

Fruit quality

The irrigations frequencies have influenced fruit quality in terms of fruit size, fruit weight, juice content, total sugar, total soluble solids, acidity and TSS: acid ratio of Kinnow mandarin, though the differences among the treatments were insignificant except in TSS, total sugar, fruit weight and cost benefit ratio (Table 1). The Kinnow plants received irrigation at 80 mm cumulative pan evaporation showed significantly improved TSS by 1.98, 0.66 and 0.42% while total sugar by 1.48, 1.43 and 0.27 % as compare to those irrigated at I_4, I_3 and I_2 treatments of irrigation frequencies, respectively. The process of fruit development is largely depends upon cell division and cell enlargement, the cell division requires the multiplication of nuclear material, proteins and the synthesis of polysaccharides to form the cell wall, and water is a structural compound of proteins and nucleic acids. Therefore, irrigation applied at (I_1) 80 mm net CPE improved the fruit quality due to favourable soil moisture regimes which might have affected nutrient uptake through moisture absorption due to transpiration and activated physiological process plants Lal *et al.* (10) found the similar results in sweet orange under agro-climatic conditions of Doon Valley. The treatments of organic mulches improved the fruit quality of kinnow mandarin over M_3 treatment (control) whereas M_1 treatment was found superior than M_2 treatment in improving the fruit quality in terms of fruit size, fruit weight, juice content, total sugar, shape index, total soluble solids, acidity, TSS: acid ratio, Peel: pulp ratio, number of seeds per fruit and number of segments per fruit. This might be due to favourable soil moisture availability for the development of fruits. These results are in close conformity with findings of Bajwa *et al.* (2) in grapes. Rathore *et al.* (17) and Verma *et al.* (29) also reported similar results in phalsa and apple, respectively.

Table 1: Effect of irrigation scheduling and mulching on physico- chemical characteristics of kinnow mandarin.

Treatment	Fruit size (cm)	Fruit weight (g)	Juice content (ml/fruit)	Total sugar (%)	TSS (%)	Acidity (%)	TSS: acid ratio
Irrigation frequency							
I_1	7.4	194.6	71.7	14.90	10.97	0.76	14.34
I_2	7.2	190.2	71.0	14.63	10.55	0.74	14.19
I_3	7.1	187.1	70.1	13.47	10.31	0.75	13.73
I_4	6.8	178.0	68.9	13.42	9.78	0.73	12.86
CD (P=0.05)	NS	14.21	NS	0.85	0.30	NS	-
Mulching							
M_1	7.3	192.1	70.6	13.80	10.14	0.75	12.25
M_2	7.1	187.5	70.1	13.55	10.04	0.73	13.69
M_3	6.9	183.0	69.0	13.39	9.91	0.74	12.16
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

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Citation : Rathore A.C., Jayaprakash, J and Mehta H. (2016). Optimization of irrigation strategies for higher biomass and fruit production in Kinnow mandarin of lower Himalaya. *HortFlora Res. Spectrum,* **5**(4) : 325-330.