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EFFECT OF IRRIGATION AND SPACING ON GROWTH, YIELD AND QUALITY BEHAVIOUR OF SWEET ORANGE ON DEGRADED LAND

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ABSTRACT : A field experiment was conducted for seven years (1986-1993) to study the effect of plant spacing and irrigation scheduling on growth, yield and quality behaviour of sweet orange cv. Malta Blood Red on degraded gravelly riverbed land of Doon valley. Irrigation applied at 15 day interval reduced the water saturation deficit of leaves and fruit drop, enchanced evapotranspiration, exhibited better tree growth and produced more fruits of superior quality than irrigation at 30 or 45 day interval and control with one life saving irrigation on May 15. Plants at 6x6 m spacing exhibited better crown spread and improved the size and weight of fruit than at 4x4m and 5x5m spacings. Plant spacing did not affect fruit yield tree^{-1}, but on per ha basis, closer spacing (4x4m) produced 2.3 and 1.6 times more fruit yield than 6x6m and 5x5m spacings, respectively.

Among citrus species, sweet orange (*Citrus sinensis*) is one of the most important fruit crops now being grown by the farmers on large scale in Doon valley. The inadequate rooting system with vestigial root-hairs in citrus species, limits the absorption of water and greater stomatal density favours a high transpiration rate. Thus, inadequate water supply may expose the plant to sub-optimal moisture conditions which would invariably affect the growth, yield and quality of fruits (Koo, 1963 and Koo and McCornak, 1985). Doon valley, although, receives about 1330 mm monsoon rains during June to September, but, the spring-summer rains are scanty, unpredictable and low (96mm) during March to Mid June. Degraded gravelly riverbed lands of Doon valley are generally poor in nutritional status and water retention which inhibit the growth of plant, hence, more number of plants can be accommodated per unit area. Thus, plant spacing and irrigation scheduling appeared two useful steps which would help in stabilizing fruit production and raising the economy of sweet orange orchards. Present investigation was, therefore, undertaken to study the effect of plant spacing and irrigation scheduling on growth, yield and quality of sweet orange orchards.

MATERIAL AND METHODS

The experiment was conducted during 1986 to 1993 at the Research Farm, Central Soil and Water Conservation Research and Training Institute, Selakui, Dehra Dun. Six profile pits (1m^3) were opened at different locations within the experimental field to assess the characteristics of soil with respect to particle size distribution (sieve analysis) and some physico-chemical parameters. Profile pit material was passed through the sieve of 2, 5, 12.5, 25, 50, 100 and 200 mm size. Fractions < 2mm were analysed for mechanical composition (International pipette method) and physico-chemical parameters (standard methods). The rainfall and open pan

evaporation received during April to June each year are given in Fig. 1.

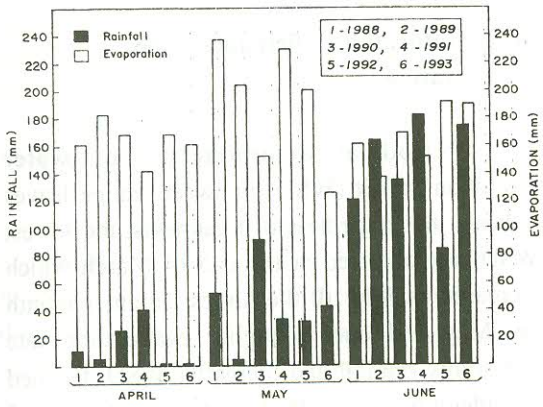

Fig. 1. Monthly rainfall and evaporation during experimental period

The experiment was laid-out in split plot design with four replications. The treatments comprised of three plant spacings i.e. 4 x 4m (S_1), 5 x 5m (S_2) and 6 x 6m(S_3) in the main plot, and irrigation schedules i.e. one life saving during 15th May as control (I_0), irrigation at 15 days (I_1), 30 days (I_2) and 45 days (I_3) intervals in the sub-plots. Irrigation treatments were imposed during April to June each year. The moisture content upto 75 cm soil depth in a circular basin of 1 m radius was considered for irrigation and amount of water corresponding to deficit was added with the help of watermeter installed at the outlet of water tanker. The volume of gravels of a circular basin of 1m radius upto 75 cm soil depth was subtracted from the total volume of the material while considering irrigation. Recommended dose of N,P,K and Zn was applied in basin soil as per the age of tree.

Observations were recorded on tree growth, fruit drop, fruit yield and quality parameters. The water saturation deficit of leaves was determined in two months old leaves of February-March growth a day before irrigation by the procedure of Barrs and Weatherley (1962). Soil moisture contents (0-75 cm depths) were determined gravimetrically on April I, before and after each irrigation, effective rainfall (2.5 mm) and on June 30. The effective rainfall between two sampling dates was added to the water use and the total water use during April to June was expressed as total evapo-transpiration by the plant.

RESULTS AND DISCUSSION

Characteristics of degraded lands

Degraded bouldery/gravelly riverbed lands have been classified into class V-VII lands as per land capability classification. The soil was slightly acidic in reaction (pH 6.5). The weight of $1m^3$ material was 1944 kg and bulk density 1.94 Mg m^3 (on wet basis). Only 30.5 per cent of the material was found less than 2 mm in size, whereas 5.2 per cent of the material was having more than 100 mm boulders/gravels. Material passed through the sieves of 2, 5, 12.5, 25, 50, 100 and 200 mm were 30.5 42.5, 60.9, 71.8, 86.1, 94.8 and 99.2 per cent, respectively. From depth wise distribution, it is observed that smaller fractions (<2mm) are dominating in upper layer (0-25 cm) and with the advancement of depth larger size particles dominates. More than 200 mm boulders were found in 75-100 cm profile depth (Fig. 2). From the mechanical composition values, it is evident that finer fractions (silt + clay) were found more in 0-15 cm layer as compared to 15-100 cm depth layer (Table 1). Coarse sand content dominated in 15-100 cm depth layer. Similarly, the chemical constituents *viz.* organic carbon, N, P and K were found more in surface (0-15 cm) layer than in sub-soil (15-100 cm) in all the six locations. The field capacity and permanent wilting point ranged from 13.8 to 5.6 and 4.9 to 2.2 per cent respectively at different soil depths (0-75

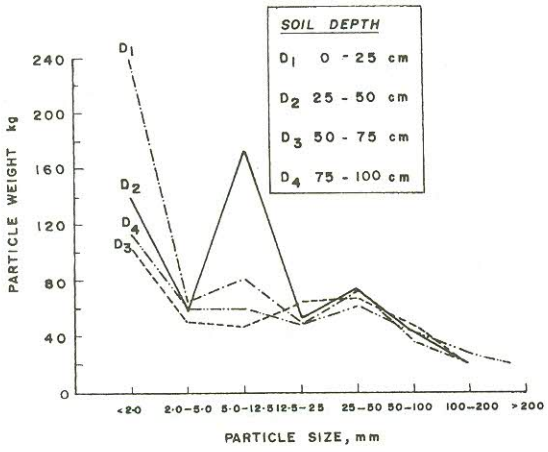

Fig. 2. Depth-wise particle size distribution in degraded bouldery/gravelly riverbed land of Doon valley.

Table 1.*Characteristics of soil*

Location	Profile depth (cm)	Sand (%)	Silt (%)	Clay (%)	Organic carbon (%)	Total N (%)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
1	0-15	46.5	36.0	17.5	0.81	0.098	70.4	273.6
	15-100	79.4	5.0	15.6	0.27	0.050	27.1	131.2
2	0-15	82.8	8.2	9.0	0.38	0.049	15.6	103.0
	15-100	91.2	2.5	6.3	0.09	0.015	6.4	46.4
3	0-15	84.0	7.8	8.2	0.51	0.070	37.7	144.0
	15-100	93.8	0.75	5.5	0.06	0.010	11.0	38.4
4	0-15	86.5	7.9	5.6	0.36	0.043	33.6	128.0
	15-100	95.0	1.0	4.0	0.59	0.013	4.1	30.4
5	0-15	29.2	51.3	19.5	0.45	0.080	17.5	208.6
	15-100	75.0	14.0	11.0	0.23	0.030	24.8	139.2
6	0-15	83.7	8.5	7.8	0.43	0.079	23.0	139.5
	15-100	93.3	2.0	4.7	0.05	0.009	9.2	48.0

cm), whereas, the bulk density of material varied between 2.0 to 1.8 Mg m^{-3}.

Water saturation deficit and evapo-transpiration

Periodical determination of water saturation deficit (WSD) in sweet orange leaves indicate that regardless of treatments, the lowest WSD was obtained at the end of March which increased rapidly till the hottest summer month i.e. May end due to higher evaporation rate and scanty rainfall and thereafter WSD declined considerably (Table 2). Irrigation applied at 15 days interval recorded the lowest WSD in leaves throughout the study period than irrigation (control). Contrary to WSD in leaves, the total evapo-transpiration increased with increasing frequency of irrigation and maximum water use by the plant was obtained with 15 days irrigation interval followed by 30 days interval. The reason for superiority of 15 days irrigation interval to minimize WSD in leaves and to improve evapo-transpiration might be due to more favourable soil moisture conditions available throughout the study period. Lal *et al.* (1990) found significant and negative

Table 2. *Water saturation deficit in sweet orange leaves and evapotranspiration under different plant spacing and irrigation scheduling (Pooled 1986-1993)*

Treatment	Water saturation deficit in leaves (%)							Evapotranspiration (cm)						Total
	March 31	April 15	April 30	May 15	May 30	June 14	June 29	At 15 days	15-30 days	30-45 days	45-60 days	60-75 days	75-90 days	
Plant spacing														
S_1	13.28	15.08	22.78	27.32	27.18	20.93	17.41	3.71	2.67	3.95	5.35	5.84	5.86	27.38
S_2	1341	14.87	24.00	28.54	28.45	21.78	16.90	3.66	2.73	4.04	5.49	5.96	5.98	27.86
S_3	13.69	15.41	24.80	30.18	30.62	22.87	17.86	3.82	2.82	4.10	5.57	6.08	6.04	28.43
Irrigation schedule														
I_0	13.48	16.61	29.10	34.51	28.13	22.93	17.79	1.85	1.68	2.30	6.06	4.53	5.85	22.27
I_1	14.03	14.24	18.48	22.80	25.10	18.47	16.67	4.29	4.89	5.87	6.34	7.55	6.77	35.71
I_2	13.70	14.63	23.19	25.37	34.57	25.86	17.98	4.36	2.13	5.44	3.45	7.24	5.64	28.26
I_3	12.61	15.00	24.67	32.04	27.20	20.18	17.12	4.42	2.26	2.51	6.03	4.52	5.58	25.32

correlation between soil moisture regime and WSD of sweet orange leaves. Sharma *et al.* (1987) also obtained similar results while working with kinnow. Plant spacing neither affected water saturation deficit in leaves nor evapo-transpiration by the plant.

Tree growth, fruit drop and yield

The planting distance of sweet orange significantly influenced the crown spread, but it could not alter the height of the trees, fruit drop and number of fruits per tree and fruit yield (q ha $^{-1}$) (Table 3). Plantation made at wider spacing (6x6m) exhibited better crown spread significantly than those planted at 4 x 4 m and 5 x 5 m spacings. The fruit yield (q ha^{-1}) increased significantly with decreasing spacing of plants and as a result,closest spacing (4 x 4 m) proved more beneficial than 5x5m and 6x6m. The magnitude of improvement in fruit yield (q ha^{-1}) attributed by 4 x 4 m spacing was of the order of 128.9 and 81.8 per cent over 6 x 6 m spacing and 61.0 and 42.9 per cent over 5 x5 m spacing during 1993 and on pooled basis, respectively. The higher fruit yield (q ha^{-1}) with close spacing was due to more number of plants accommodated per unit area than wider spacings.

Table 3. *Effect of plant spacing and irrigation scheduling on tree growth, fruit drop and yield of sweet orange*

Treat-ment	Tree height 1993 (m)	Crown spread 1993 (m)	Av. fruit drop (1989-93) (%)	Fruit yield (1993)		Av. fruit yield (1989-93)	
				No. tree^{-1}	q ha^{-1}	No. tree^{-1}	q ha^{-1}
Plant spacing							
S_1	2.06	1.43	78.6	33.5	29.69	22.6	19.78
S_2	2.01	1.44	83.6	32.3	18.44	24.2	13.84
S_3	1.91	1.70	80.9	32.0	12.97	26.4	10.88
CD (P= 0.05)	NS	0.22	NS	NS	3.28		
Irrigation schedule							
I_0	1.86	1.39	91.2	23.0	13.45	17.2	9.56
I_1	2.17	1.81	65.6	48.3	32.04	37.8	25.18
I_2	2.07	1.49	79.0	34.7	21.66	24.2	14.44
I_3	1.86	1.40	88.3	24.3	14.31	18.4	10.15
CD (P= 0.05)	0.17	0.15	7.1	3.6	2.37		

The frequency of irrigation influenced the plant growth characters, fruit drop and fruit yield significantly. Irrigation applied at 15 days interval exhibited better tree height and crown spread and reduced the fruit drop (%) significantly as compared to 30 to 45 days interval and one life saving irrigation. However, frequent irrigations (15 days interval) improved the number of fruits per tree and produced more fruits (q ha $^{-1}$) significantly than those irrigation at 30 or 45 days interval and one life saving irrigation. The magnitude of improvement in fruit yield (q ha^{-1}) attributed by 15 days irrigation interval was to the tune of 47.9, 123.9 and 138.2 per cent during 1993 and 74.4, 148.1 and 163.4 per cent on pooled basis over 30 days interval, 45 days interval and one life savings irrigation, respectively. The superiority of 15 days irrigation interval over other irrigation treatments might be due to more favourable soil moisture conditions available throughout the crop period which attributed more photosynthates and uptake of nutrients utilized by the leaves with greater efficiency. Mageed (1983) and Hirobe and Ogaki (1974) also obtained similar results.

The interaction effect between plant spacing and irrigation scheduling (SXT) on fruit yield (q ha^{-1}) was also significant (Table 4). The closer spacing (4 x 4 m) produced more fruit yield at each frequency of irrigation than wider spacings. However, irrigation applied at 15 days interval enchanced fruit yield significantly at each distance of planting than

other irrigation treatments. Sweet orange plants planted at closer spacing (4x4m) and irrigated at 15 days interval (S_1 I_1) exhibited superiority over other treatment combinations and produced as much as 48.39 and 34. 29 q ha^{-1} fruits during 1993 and on pooled basis, respectively. The favourable yield response at closer spacing and 15 days irrigation interval was due to combined

Table 4. *Interaction effect of plant spacing and irrigation scheduling on fruit yield (q ha^{-1}) of sweet orange*

Treatment	1993 Plant spacing			(Av. 1989-93) Plant spacing		
	S_1	S_2	S_3	S_1	S_2	S_3
Irrigation schedule						
I_0	17.75	13.68	8.92	12.38	8.96	7.33
I_1	48.39	27.70	20.03	34.29	23.40	17.84
I_2	31.70	19.95	13.33	19.21	13.48	10.63
I_3	20.90	12.43	9.59	13.22	9.51	7.72
Mean	29.69	18.44	12.97	19.78	13.84	10.88
CD (P=0.05)	4.11					

effect of more number of plants accomodated per unit area and more favourable soil moisture conditions available through out the crop period attributed better fruit retention and more uptake of nutrients utilised by the plants.

Fruit quality

A perusal of the data presented in Table 5 clearly indicate that planting distance of sweet orange did not influence the quality of fruits with respect to their size, weight, rind thickness, juice content, number of seeds, acidity and total soluble solid (TSS) considerably.

Sweet orange tree irrigated at 15 days interval produced better quality fruits in terms of size, weight and juice content as compared to other irrigation treatments. It is a well known fact that the process of fruit development largely depends upon cell division and cell enlargement, the former 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. Hence, 15 days irrigation interval improved the fruit quality in terms of size, weight and juice content due to more favourable soil moisture conditions available

Table 5. *Fruit quality of sweet orange as influenced by plant spacing and irrigation scheduling*

Treatment	Fruit size (cm)	Fruit weight (g)	Rind thickness (mm)	Juice content (ml $fruit^{-1}$)	Seed (No. $fruit^{-1}$)	Acidity (%)	T.S.S. (^{0}B)
Plant spacing							
S_1	6.13	136.4	3.8	52.5	21.4	0.59	17.67
S_2	6.35	139.6	3.9	52.8	23.0	0.63	18.21
S_3	6.42	145.2	3.7	54.0	22.2	0.61	17.94
Irrigation schedule							
I_0	6.11	132.6	4.1	48.5	22.0	0.57	18.42
I_1	6.64	156.4	3.6	65.2	24.2	0.66	17.62
I_2	6.33	141.2.	3.7	52.5	21.5	0.62	17.34

during fruit development stage. Similar results have also been reported by Ghosh (1985) in case of sweet lime under the same agro-climatic conditions.

From the foregoing study, it can be concluded that even in degraded bouldery/ gravelly riverbed lands the economic yield of sweet orange can be obtained by planting them at closer spacing (4x4m) alongwith limited irrigation (at 15 days interval) during April to June only.

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