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Micro-climatic Assessment and Thermal Time Requirement in Relation to Datepalm Fruit Maturity in Arid Rajasthan

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Abstracts: Micro-climatic changes inside the irrigated datepalm (*Phoenix dactylifera*) orchard of 14 to 18-year-old plantation with 8 x 8 metre spacing were studied during three consecutive years, 1993-95, at CR Farm, Jodhpur. The change in micro-climate of the orchard is mainly due to dropping of air temperature, decrease in saturated vapour pressure deficit (SVPD) by 2 to 5 mb and reduction in wind speed compared to that outside the orchard. This indicated the possibility of growing summer and rainy season vegetable crops inside the orchard. Relationships between onset of various phenological growth stages in three promising cultivars of datepalm (viz; Halawy, Shamran and Zahidi) and ambient temperature were also worked out. It is found that the datepalm fruit required 2304 to 2601°Cd heat unit to reach at doka maturity stage after spathe emergence. However, dang maturity stage required heat unit about 2769 to 2879°Cd, which is normally not possible under Jodhpur condition before the start of rainy season.

Key words: Datepalm, micro-climate, fruit size, total soluble solids, fruit maturity, thermal time availability.

Western Rajasthan is characterised by the conditions of high aridity, with low and erratic rainfall. The atmosphere is hot and very dry with maximum temperature exceeding 40°C and vapour pressure deficit exceeding 30 mb in May and June. Therefore, the fruit crops selected must be such that their fruit maturity requires more heat and coincides with the period of maximum heat availability in the atmosphere. Fruit crops like datepalm (*Phoenix dactylifera*), which is a heat-loving plant, conform to this prerequisite (Pareek, 1977; Chandra *et al.*, 1994). Crop flower during February and March, and fruit ripening is over by June or middle of July (before the arrival of monsoon in western Rajasthan). There is no study reported so far on the micro-climates of datepalm orchard grown under arid tropical condition. Therefore, the present study was undertaken to quantify the micro-climate of the datepalm orchard grown under arid western Rajasthan.

Materials and Methods

A field experiment was conducted in an established datepalm (*Phoenix dactylifera*) orchard (Table 1), located at Central Arid Zone Research Institute, Jodhpur. The area receives normal annual rainfall of 368 mm against the potential evapotranspiration of 1842 mm. The soil of the experimental site is sandy loam and moderately deep (50-75 cm), over a hard *Kankar* (*Murram*) layer. Three cultivars of datepalm were planted

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Table 1. Growth characteristics of datepalm cultivars

Cultivars	Year of plantation	Age of plant (year)	Height (cm)	Green leaves per plant	No. of dead leaf scars
Halawy	1982	14	480	32	115
Shamran	1978	18	590	36	128
Zahidi	1982	14	430	40	78

separately in rows at a spacing of 8 x 8 m. Observations were recorded at periodical interval three times (9 am, 12 noon and 3 pm) in a day from September to June. The net radiation, albedo, soil heat flux, profiles of radiation, humidity and air temperature were measured. Air temperatures and humidity profiles were recorded using an Assman Psychrometer. The net radiation and soil heat flux were obtained using a Funk Type radiometer and heat plates, respectively. Tube solarimeter was used for measurement of radiation interception by the canopy. Daily wind observations were carried out in datepalm orchard using digital Cup anemometer at three heights (50 cm, 120 cm and at the height of datepalm).

The heat units (thermal time) were computed using mean daily air temperature minus base (threshold) temperature of 100°C (Pareek, 1977; Singh *et al.*, 1998) during the last 30 years (1966-95) from February to June to work out the normal availability of thermal time in degree celsius day (°Cd). Daily values of the units were also summed up for each development stage from spathe emergence (1st week of February) to doka stage (2nd fortnight of June) and dang stage of fruit maturity (1st fortnight of July) during the field experimental periods (1993-95). Fruit samples from each cultivar were harvested and collected randomly from all directions at different development phases at 15 day intervals. Fruit length and width were measured with the help of Vernier Callipers. Total soluble solids (TSS) were measured in degree brix using Hand Refractometer. Fruits were harvested randomly from different cultivars at different stages and immediately brought to laboratory for the TSS measurements.

Results and Discussion

Micro-climate of datepalm orchard

Micro-climate is quantified with the distribution of wind speed, temperature and humidity near the ground and with the various factors which influence these weather parameters. The most important of these are fluctuations in the energy and water balances and the nature and characteristics of the vegetation (Krishnan and Rao, 1978).

Net radiation (R_n)

Temporal and seasonal variation and profiles of incoming solar radiation (Rs) and net radiation (Rn) were studied under the canopy of datepalm cultivars. The importance of net radiation is that it is the fundamental quantity of energy available at any surface to drive the process of evaporation, air and soil heat flux as well as other energy-consuming processes such as photosynthesis. Data recorded on net

(a)

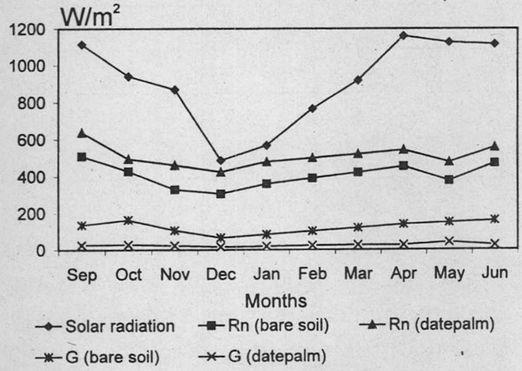

Fig. 1a. Monthly variation of energy balance components over bare soil and datepalm canopy during peak day hour.

(b)

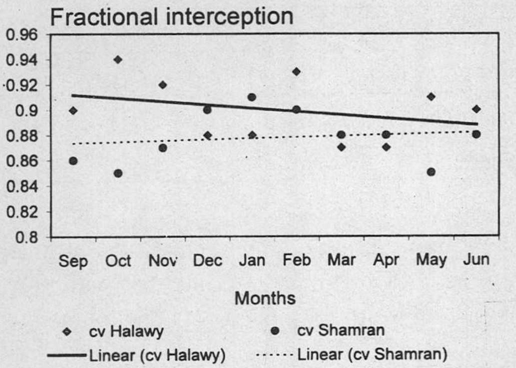

Fig. 1b. Fractional interception of solar radiation by different canopies of datepalm cultivars.

radiation (Fig. 1a) indicated that bare soil had the lower R_n because of higher soil temperatures and higher albedo in comparison to the canopies of datepalm. The seasonal variation in net radiation was recorded between 425 and 638 Wm^{-2} over the orchard against the 306 to 510 Wm^{-2} over the bare soil at peak day hour.

Soil heat flux (G)

The soil heat flux was monitored in bare soil as well as soil below the canopies of datepalm to compare its contribution to energy balance. Soil heat flux measured in Wm^{-2} revealed that more heat was penetrating into bare soil, maximum up to 163.7 Wm^{-2}, in comparison to soil below datepalm (41.0 Wm^{-2}) during peak day hour in summer months (Fig. 1a). This indicated that hardly 10% of the net radiation received over the canopy was going into the soil and rest of the net radiation was partitioned into latent heat flux (utilized in evapotranspiration by datepalm), sensible heat flux (raising of ambient temperature) and photosynthesis process.

Light interception by canopy

Solar radiation measured above and below the canopies of datepalm revealed that interception of light was more by cultivar Halawy (86-94%) than by Shamran (84-92%). This lower interception of light (Fig. 1b) by Shamran cultivar was mainly due to its open canopy. Light intercepted by canopies of Halawy and Shamran cultivars during different periods and stages of crop are also presented in the above figure. It shows a curve of sinusoidal nature in case of Halawy and parabolic in case of Shamran canopy.

Monthly variation of light intensity and photoperiod over the orchard

The mean daily radiation (MJ m^{-2}) varied from 25.7 in May to 11.1 in December, whereas sun shine hours (hrs day^{-1}) ranged from 11.1 in May to 6.4 in August (Table 2) over the orchard. During the fruit development period, (April-June), the mean daily photoperiod was the highest up to 11.1 hours day^{-1} and mean daily radiation was maximum up to 25.7 MJ m^{-2}. This

Table 2. Global radiation (MJ m^{-2} day^{-1}) and bright sunshin (hrs day^{-1}) recorded over the orchard

Parameters	1992						1993					
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Radiation	18.0	16.6	19.4	18.4	13.4	11.1	12.9	6.8	20.8	23.7	25.7	24.3
Sunshine	6.8	6.4	8.7	9.9	9.7	9.0	8.7	9.3	9.9	10.2	11.1	10.2

is a major climatic characteristics of the region, and fortunately coincides with the heat requirement period of the plant.

Temperature profile

Air temperature profile observed up to 2m height in the datepalm orchard below the tree indicated that air temperature inside the orchard is always less by 0.5 to 2.5°C during all growth stages of the datepalm as compared to that in open bare field adjacent to the orchard. The difference in the temperature between inside and outside orchard is less during the forenoon in comparison to the afternoon period (Fig. 2a).

In general, the temperature recorded below the Shamran cultivar was less than the temperature below the Halawy cultivar, particularly during the afternoon period at all the stages from spathe opening to dang maturity stage of the datepalm fruit.

Saturation vapour pressure deficit (SVPD)

Saturation vapour pressure deficit,which indicated the dryness of the surrounding atmosphere and exerted pressure on plant for more transpiration, was computed and is presented in Fig. 2b. SVPD inside the orchard varied between 51 and 98 mb in the afternoon, whereas outside the orchard it varied between 52 and 104 mb during March to June. Lower values were recorded

(a)

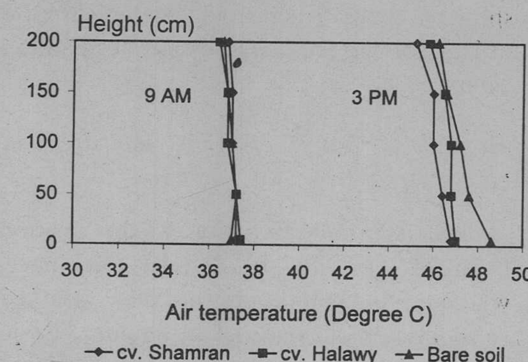

Fig. 2a. Air temperature profile below canopies of datepalm as well as over bare soil on June 3, 1995.

(b)

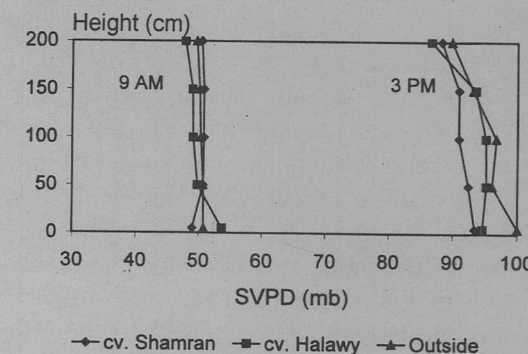

Fig. 2b. Saturation vapour pressure deficit (SVPD) inside and outside datepalm orchard on June 3, 1995.

Table 3. Wind speed profile and wind reduction inside the orchard

Height (cm)	Wind speed (m s^{-1})											
	July		August		September		October		November		December	
	Obs.	Orc.	Obs.	Orc.	Obs.	Orc.	Obs.	Orc.	Obs.	Orc.	Obs.	Orc.
50	1.50	0.73 (51)	1.20	0.65 (46)	0.92	0.56 (39)	0.55	0.49 (11)	0.40	0.40 (0)	0.61	0.50 (18)
120	1.70	0.83 (51)	1.40	0.75 (46)	1.00	0.56 (35)	0.64	0.52 (19)	0.61	0.36 (25)	0.70	0.53 (24)
At plant height	1.90	0.72 (62)	1.60	0.70 (56)	1.20	0.69 (43)	0.64	0.53 (17)	0.44	0.43 (02)	0.94	- (-)

Note: Obs.: observatory; Orc.: inside orchard.

in March and higher during peak summer month of June.

However, at 9 am, the vapour pressure deficit was not too high and it was almost half of the values reported for the afternoon period. SVPD was lower inside the orchard in comparison to outside. This was mainly due to irrigation which increases the moisture content of the air inside the orchard. On an average, the difference in saturation vapour pressure deficit between inside and outside the orchard was approximately 2 mb for the forenoon and 5 mb for the afternoon period.

Wind distribution

Mean monthly wind speed varied between 0.40 to 0.73, 0.36 to 0.83 and 0.43 to 0.72 m s^{-1} at 50 cm, 120 cm and at the plant height, respectively. Wind reduction was more (35 to 62%) during rainy season (July-Sept.) than post-monsoon (11 to 19%) and winter season (Table 3).

The modification of micro-climate inside the datepalm orchard due to dropping of the air temperature by 0.5 to 2.5°C and decrease in SVPD by 2 to 5 mb, in combination with the reduction in wind speed, indicated the possibility of growing the summer vegetable crops under the arid conditions. However, kharif pulses and leguminous crops can be suggested to grow as intercrops with datepalm during the rainy season under rainfed conditions.

Fruit development and thermal time relationship

Relationship between datepalm fruit size (cm) and accumulated heat units after fruit setting for two cultivars (Shamran and Zahidi) were worked out (Fig. 3 a,b). In both cases hoerl function of a type of Y = A*BX*XC was fitted, which is a combination of product of power curve and exponential type curve. This could explain 96 to 98% and 89 to 97% variation in fruit development of Shamran and Zahidi cultivars, respectively.

This reveals that in spite of taking almost similar time for fruit setting by both the cultivars, the fruits of Shamran cultivar grow slightly faster with thermal time (about 77.9 and 201.7°Cd per mm increase in length and width of the fruit, respectively) in comparison to the fruits of Zahidi cultivar, which grow slowly and require more thermal time (87.6 and 274.4°Cd per mm increase

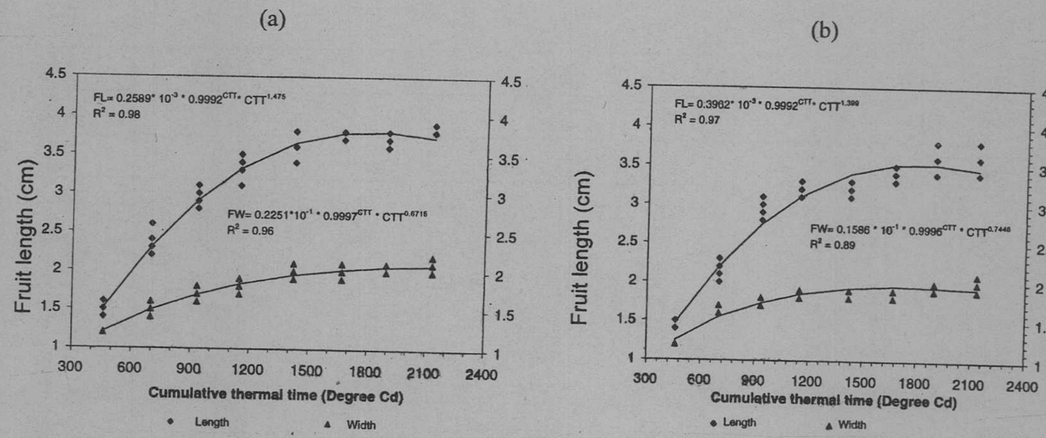

Fig. 3. Fruit development of datepalm with cumulative thermal time, CTT (a) cv. Shamran (b) cv. Zahidi.

in length and width of the fruit, respectively). These linear regressions in Fig. 3a,b also indicate that fruit development response with ambient temperature is more in Shamran than Zahidi cultivar. Similar findings on effects of temperature and heat units were reported by O'Brien *et al.* (1983), Menzel and Simpson (1988) and Singh *et al.* (1998, 1999) for other horticultural crops.

Total soluble solids (TSS) and thermal time relationships

The TSS (degree brix) measurement were carried out at various growth stages and the data were used to develop the linear relationship with cumulative thermal time from fruit setting stage (Fig. 4 a,b). Though TSS of Shamran fruit was reported slightly higher than the fruits of Zahidi cultivar, variation in TSS with thermal time was better explained up to 95% in Zahidi cultivar in comparison to the Shamran cultivar (83%). In general, 69.3 to 72.9°Cd heat was required to increase TSS by 1 degree brix after the fruit setting. TSS in datepalm fruits was found 8.0 to 8.6 degree brix during the first fortnight of fruit setting irrespective of cultivar. However, at fruit maturity, the value of TSS was measured as 33.6 degree brix in Zahidi and 36.8 degree brix in Shamran cultivar (Vashishtha and Pareek, 1978) in the region. Nilsson (1988) also indicated that hexoses, sucrose and total sugar in head leaves of cabbage were more strongly correlated with degree-days (heat units).

Table 4. Thermal time required for the maturity of datepalm fruits after spathe emergence

Cultivar	Spathe opening			Doka stage			Dang stage		
	1993	1994	1995	1993	1994	1995	1993	1994	1995
Halawy	224	187	165	2601	2601	2664	2857	–	2831
Shamran	168	151	113	2601	2304	2661	2879	2446	2806
Zahidi	196	188	152	2686	2496	2675	2778	2733	2769

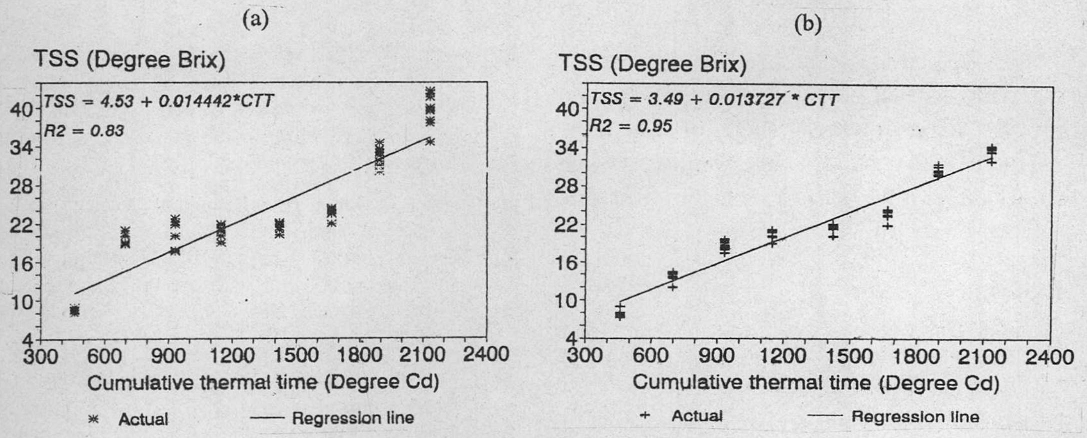

Fig. 4. Total soluble solids (TSS) in datepalm fruits with cumulative thermal time, CTT (a) cv. Shamran (b) cv. Zahidi.

Thermal time availability and datepalm fruit maturity

Datepalm growth favoured hot climate and its fruits required high temperatures during maturity. Study revealed that the datepalm fruit took 2304 to 2601°Cd to reach doka maturity stage (Table 4). This much availability of thermal time at Jodhpur and its surrounding regions is normally possible (Fig. 5) in the region from February to end of June (before the onset of south west monsoon). However, the dang maturity stage required more thermal time (about 2769 to 2879°Cd) than doka maturity stage. Therefore, datepalm fruits should be harvested at doka stage under Jodhpur conditions. Waiting for harvest of fruits at the dang maturity stage is full of risk and it is possible only in case of delay in the arrival of monsoon beyond middle of July (Mertia and Vashishtha, 1985) in the region. Isenberg *et al.* (1975) and Singh *et al.* (1999) also used heat units and solar radiation to predict the maturity of vegetable and fruit crops for storage.

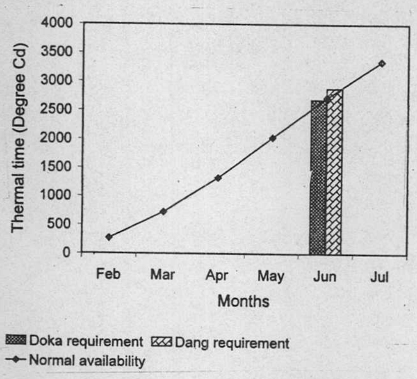

Fig. 5. . Thermal time availability for fruit maturity of datepalm at Jodhpur (1966-95).

Conclusions

The modification of microclimate inside the irrigated datepalm orchard due to drop in air temperature and SVPD, in combination with the reduction in wind speed, had indicated the possibility of growing the summer vegetable crops under arid conditions. However, kharif pulses and other leguminous crops may be recommended to grow as intercrop with datepalm during the rainy season to utilize the interspace and favourable crop growing environment inside the orchard.

Farmers are also advised to harvest the datepalm fruit at doka stage and not to wait for the dang maturity stage of the crop, as there is a risk for deterioration of the fruit quality and damage of the fruit due to the onset of monsoon.

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