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Variation in carbon fixation and water use efficiency among date palm cultivars grown in arid zone

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Abstract

Seven commercial cultivars of date palm (Halawy, Khadrawy, Shamran, Zahidi, Medjool, Khuneizi and Khalas) were evaluated on the basis of physiological parameters. The net photosynthetic rate, transpiration, stomatal conductance and internal CO_2 concentration were estimated using LI-6200 Infra Red Gas Analyzer. The values of carboxylation efficiency and water use efficiency were computed. The results demonstrate that in date palm maximum rate of photosynthesis occurs during spathe emergence stage, which shows that probably this stage has a high sink demand. It was further noticed that higher rate of photosynthesis in date palm is on account of higher stomatal conductance. Inter-cultivars comparison revealed that cv. Halawy might have advantage over others in hot arid ecosystem, as this cultivar possesses high rate of photosynthesis, water use efficiency and carboxylation efficiency.

Key words: *Arid ecosystem , date palm, carboxylation efficiency, photosynthesis*

Introduction

Date palm (*Phoenix dactylifera* L.) is a potential fruit tree of Indian arid ecosystem. Its nutritious fruits having high calorific value are eaten as raw dates (fresh khalal fruits), dry dates (*chuhhara*) and soft dates (tamar). It is suitable for cultivation on marginal lands even if irrigated with saline water. Because of tolerance to high salinity, aridity and maximum temperature (48°C), date palm is a hardy fruit tree of semi arid and arid regions. Various attempts have been made in past to evaluate the varietal characters of date palm cultivars on the basis of morphological parameters (Chandra *et al.*, 1990) isozyme patterns (Al-Helal, 1988; Al Jibouri and Adhan, 1990) and flavonoid spectrum (Ouafi *et al.*, 1988). However, the work on the growth and development particularly on photosynthetic efficiency of date palm cultivars is rare. Moreover, it has been pointed out that lower loss of water through foliar transpiration (Singh *et al.*, 1998) effectively control water loss by stomatal closure under water stress, higher intrinsic water use efficiency (Jones, 1992) and increase in content of hexose sugar and proline (Clifford *et al.*, 1997) are some of the important characterstics of drought tolerant plants such as ber.

Accordingly, the present study was undertaken with the aim to compare seven cultivars of date palm on the basis of physiological parameters with a view to identify most suitable cultivar, which can thrive best in arid ecosystem. The results thus obtained constitute the text of the present communication.

Materials and methods

The study was conducted during the year 2001-2002 in the National Repository of Date palm at Central Institute for Arid Horticulture, Bikaner situated at 28.01° North latitude and 73.22° East longitude at an altitude of 234.70 meter above mean sea level. The soil of this region is sandy and low in organic matter. The uniform plants of seven commercial cultivars viz. Halawy, Khalas, Khuneizi, Medjool, Khadrawy, Zahidi and Shamran were selected for the study. The study was carried out on four-years old palm trees in three replications. The plants were maintained under normal cultural practices and irrigation was done at 15 days interval. For photosynthesis measurement, middle leaflet of expanded leaves were chosen at all stages on the same plant. The data on photosynthetic rate, transpiration, stomatal conductance was measured using LI-6200 Infra Red Gas Analyser (LICOR, USA). The observations were recorded between 10 to 11 h at all the four stages viz. vegetative growth, spathe emergence, fruit set and fruit development. The value for carboxylation efficiency was computed as ratio of photosynthetic rate to internal CO_2 concentration and water use efficiency as ratio of photosynthetic rate to transpiration as described by Das et al. (1999). Since the observations were taken in germplasm block, the data was statistically analyzed using CRD with the help of MSTAT software.

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Results and discussion

Photosynthetic rate

The results obtained on photosynthetic rate in seven cultivars of date palm are presented in Table 1. Perusal of data reveals that at vegetative stage cv. Shamran had significantly the highest net photosynthetic rate (15.46 μmol m^{-2} s^{-1}) followed by Khalas and Halawy. At spathe emergence stage the maximum photosynthetic rate was observed in Shamran (16.09 μmol m^{-2} s^{-1}) followed by Zahidi (15.34 μmol m^{-2} s^{-1}) and Medjool. However, Khuneizi and Khalas cultivars had low rate at this stage. At fruit initiation stage the net photosynthetic rate was at par in Shamran, Halawy, Khuneizi and Medjool. Similarly at fruit development stage, the maximum net photosynthetic rate was in Zahidi (13.31 μmol m^{-2} s^{-1}) followed by Khuneizi, Halawy and Khalas while lowest net photosynthetic rate was observed in cultivar Khadrawy. The significant observation which emerge from the present study is that the net photosynthetic rate in all the cultivars was highest at the spathe emergence stage. This illustrate that the plant has a high sink demand at this stage.

Table 1. Photosynthetic variation (μmol m^{-2} s^{-1}) in date palm cultivars

Variety	Stage			
	Vegetative growth	Spathe emergence	Fruit set	Fruit development
Halawy	13.30	14.36	11.52	7.99
Khadrawy	12.39	13.55	7.48	5.93
Shamran	15.46	16.09	11.51	6.52
Zahidi	11.65	15.34	10.79	13.31
Medjool	12.22	14.74	11.23	7.17
Khunezi	10.69	12.48	11.93	8.19
Khalas	13.41	12.15	10.59	7.87
C D at 5%	0.571	0.964	0.844	2.19

The leaf CO_2 assimilation in date palm has been studied in past by Al-Whaibi (1988) where he compared the rates in cvs. Sukkeri and Osaila and reported that Osaila has 13% higher rate than cv. Sukkeri. The results are also in line with the above and demonstrate inter cultivar variations in photosynthetic rates. Thus, taking into consideration the stage at which plants have highest net photosynthetic rate (spathe emergence), the cultivars could be classified into 2 groups:

Group A- having higher net photosynthesis rate (more than 14 μmol m^{-2} s^{-1}). (Halawy, Shamran, Zahidi, Medjool)

Group B- having low net photosynthetic rate (less than 14 μmol m^{-2} s^{-1}). (Khadrawy, Khuneizi and Khalas)

Transpiration

The data pertaining to transpiration rate in seven commercial cultivars of date palm are depicted in Table 2.

Table 2. Variation in transpiration rates (mmol H_2O m^{-2} s^{-1}) in date palm cultivars

Variety	Stage			
	Vegetative growth	Spathe emergence	Fruit set	Fruit development
Halawy	5.45	2.82	3.65	4.44
Khadrawy	5.49	2.74	5.89	5.54
Shamran	8.48	4.14	6.27	5.94
Zahidi	6.39	4.05	6.01	6.33
Medjool	6.11	4.11	5.39	5.94
Khunezi	5.46	3.78	6.24	4.85
Khalas	6.89	3.50	4.64	5.54
C D at 5%	0.091	0.054	0.079	0.073

Perusal of data reveals that at vegetative growth stage Shamran shows maximum transpiration rate (8.48 mmol H_2O m^{-2} s^{-1}) followed by Khalas, Zahidi and Medjool. The minimum value was recorded in cvs. Halawy and Khuneizi.

At spathe emergence stage, the transpiration rate was low in all the cultivars. The maximum rate was observed in Shamran and Medjool and lowest was in cvs. Khadrawy and Halawy showing thereby that the plant of Khadrawy and Halawy are able to conserve water under low moisture availability by reducing their transpiration rate. Similar pattern was observed at fruit initiation and fruit development stages also.

Stomatal conductance

The data on stomatal conductance in seven cultivars at different growth stages are presented in Table 3. Perusal of data reveals that at vegetative growth stage the stomatal conductance in cvs. Shamran, Zahidi and Medjool were high whereas Khadrawy showed least value (4.411 cm s^{-1}). However at all other stages the date palm plants maintained lower rate of stomatal conductance (<4.0 cm s^{-1}) as compared to vegetative growth stage. This is illustrated by the fact that at spathe emergence stage the highest value recorded was 3.997 cm s^{-1} in cv. Shamran. The same cultivar showed highest stomatal conductance (3.88 cm s^{-1}) at fruit

Table 3. Variation in stomatal conductance in date palm cultivars (cm s^{-1})

Variety	Stage			
	Vegetative growth	Spathe emergence	Fruit set	Fruit development
Halawy	5.178	3.568	2.579	2.035
Khadrawy	4.441	2.640	2.708	1.983
Shamran	6.849	3.997	3.88	2.041
Zahidi	6.529	3.922	3.298	2.850
Medjool	6.083	3.868	2.490	2.696
Khunezi	4.488	3.588	3.824	2.216
Khalas	4.518	3.564	3.600	3.686
C D at 5%	1.151	0.392	0.407	0.788

initiation stage and cv. Khalas (3.68 cm s^{-1}) at fruit development stage.

The studies conducted by Al-Whaibi (1988) have demonstrated that higher rate of photosynthesis and water use efficiency of date palm cv. Osaila is on account of high stomatal conductance. In this study also it has been observed that cultivars having higher rate of CO_2 assimilation and transpiration also have higher rate of stomatal conductance. For instance at spathe emergence stage, cv. Shamran showed has highest rate of net photosynthesis (16.09 µmol m^{-2} s^{-1}), high transpiration rate (4.14 mmol H_2O m^{-2} s^{-1}) and high rate of stomatal conductance too (3.997 cm s^{-1}). Thus, it indicates that the high rate of photosynthesis in date palm cultivars is on account of higher stomatal conductance. This finding is in accordance with the results reported by Al-Whaibi (1988).

Carboxylation efficiency

The data on carboxylation efficiency was calculated using the net photosynthetic rate and internal CO_2 concentration. The results demonstrate that at vegetative growth stage the maximum carboxylation efficiency was recorded in cvs. Shamran and Halawy followed by Khalas, Khadrawy and Medjool. At spathe emergence stage, the maximum carboxylation efficiency was observed in cv. Shamran and Halawy followed by Zahidi. Similarly, at fruit initiation stage, the maximum carboxylation efficiency was recorded in Shamran followed by Khuneizi and Halawy. Similar results were also obtained at fruit development stage (Table 4).

Table 4. Variation in carboxylation efficiency in date palm cultivars

Variety	Stage			
	Vegetative growth	Spathe emergence	Fruit set	Fruit development
Halawy	0.0511	0.0501	0.0426	0.0294
Khadrawy	0.0468	0.0432	0.0271	0.0213
Shamran	0.0598	0.0517	0.0434	0.0231
Zahidi	0.0400	0.0489	0.0405	0.0467
Medjool	0.0459	0.0400	0.0419	0.0263
Khunezi	0.0373	0.0425	0.0440	0.0302
Khalas	0.0483	0.0392	0.0403	0.0293
C D at 5%	0.0147	0.0031	0.0040	0.0031

Thus, on the basis of carboxylation efficiency at spathe emergence stage (since the photosynthetic rate was maximum at this stage), the cultivars can be classified into 2 groups viz.,

Group A- having carboxylation efficiency more than 0.045 (Halawy, Shamran, Zahidi)

Group B- having carboxylation efficiency less than 0.045 (Khadrawy, Medjool, Khuneizi and Khalas)

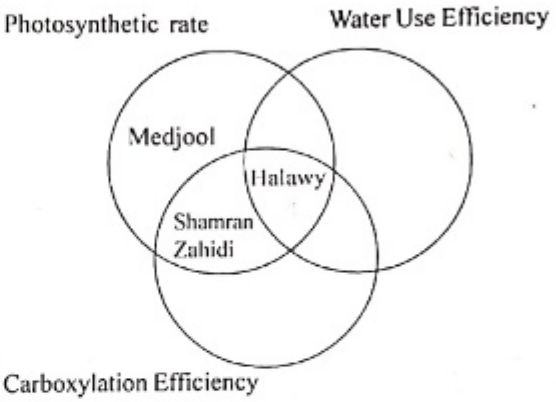

Fig. 1. Venne Diagram showing distribution of date palm cultivars on the basis of physiological parameters.

Water use efficiency

The data on water use efficiency in date palm cultivars at four growth stages is presented in Table 5. The data reveal that at vegetative growth stage cv. Halawy had the maximum water use efficiency (2.44 µmol CO_2 fixed/ mmol of H_2O transpired) followed by Khadrawy (2.25 µmol CO_2 fixed/ mmol of H_2O transpired). At spathe emergence stage, the maximum water use efficiency was in cv. Halawy (5.09 µmol CO_2 fixed/ mmol of H_2O transpired) followed by Khadrawy (4.94 µmol CO_2 fixed/ mmol of H_2O transpired). All other cultivars showed value less than 4.0. At fruit initiation stage and fruit development stage, the water use efficiency was comparatively low in all the cultivars. At fruit initiation stage, the maximum water use efficiency was recorded in Halawy followed by Khalas and Medjool whereas at fruit development stage Zahidi demonstrated maximum water use efficiency.

Table 5. Variation in water use efficiency (µmol CO_2 fixed/ mmol of H_2O transpired) in date palm cultivars

Variety	Stage			
	Vegetative growth	Spathe emergence	Fruit set	Fruit development
Halawy	2.44	5.09	3.15	1.79
Khadrawy	2.25	4.94	1.26	1.07
Shamran	1.82	3.88	1.83	1.09
Zahidi	1.82	3.78	1.79	2.10
Medjool	2.00	3.58	2.08	1.20
Khunezi	1.95	3.30	1.91	1.68
Khalas	1.94	3.47	2.28	1.42
C D at 5%	0.05	0.06	0.03	0.03

Inter cultivar comparison revealed that at all the stages Halawy showed the best water use efficiency. Accordingly, the cultivars could be classified into two groups on the basis of WUE at spathe emergence stage:

Group A- water use efficiency high (>4.0) cvs. Halawy and Khadrawy.

Group B- water use efficiency low (<4.0) cvs. Shamran, Zahidi, Medjool, Khuneizi and Khalas.

In our study, we compared all the seven cultivars on the basis of physiological parameters with a view to assess the cultivars which can grow successfuly in arid ecosystem. The criteria taken were high rate of photosynthesis along with low transpiration and high water use efficiency. Accordingly, the cultivars were classified into groups based on their performance in the field. It was observed that Halawy, Shamran and Zahidi are the cultivars which shows better physiological performance under arid ecosystem. Thus our findings suggests that Cvs. Halawy, Shamran and Zahidi can be cultivated in hot arid region of Rajasthan. Our findings are in line with those suggested by Chandra *et al.* (1990) while evaluating the date palm on the basis of yield and quality attributing characters who also recommended suitability of cv. Halawy for arid region.

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