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Physiological traits of Kinnow mandarin under Drip irrigation system

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Abstract

Variation in plant environmental factors of Kinnow mandarin for at Agriculture Research Station, SriGanganagar district of Rajasthan state in India with respect to three differential irrigation treatments revealed that overall maximum carboxylation efficiency (A) was estimated in 70% Etc treatment from April to June with a linear trend and showed depression in September and October followed by a steady rise in November and December months. Stomatal conductance revealed oscillating trend being maximum in 70% Etc treatment for April and May months followed by steep rise in 40% Etc treatment for June –July months and remained static in August and September, a trend reversal in October-November with maximum stomatal conductance in 100% Etc treatment with a slight compared to 70% Etc. The cumulative overall high stomatal resistance in 40% treatment might have attributed to low photosynthetic rates followed by 100% treatment and the better assimilation rates under 70% treatment are correlated with low rates of stomatal resistance. The daily course of transpiration in all the three irrigation treatments does not closely linked to solar irradiation but rather to leaf temperature. Temperatures of 25-30°C are optimal for photosynthesis but temperatures above 30°C definitely reduce photosynthetic activity.

The annual trend for three consecutive years' data revealed occurrence of cyclic oscillations in photosynthesis, stomatal conductance, stomatal resistance, transpiration rate and photosynthetic active radiation under field conditions. Citrus belong to C_3 plants, with photosynthetic rates lower than C_4 plants. Assimilation rates ranging from 1.28 to 7.93 mmolm^{-2}s^{-1} observed under differential irrigation treatments seem realistic under optimal irrigated conditions of Western Rajasthan.

Key Words: Kinnow, photosynthesis, carboxylation efficiency, stomatal conductance

Introduction

Carbon assimilation efficiency during the cumulative day hours of the year determines plant growth and productivity. This efficiency is a compound effect of net photosynthetic rate and photosynthate partitioning. Measurements of photosynthesis rate, transpiration rate, Stomatal conductance have been very important for understanding limitations in assimilation potential of plants. The weather parameters in conjunction with irrigation optima influence/cause these variations (Maroco *et al*., 1997). Direct effect of leaf to air vapour pressure deficit in Stomatal regulation was reported in many woody crops (Flore and Lakso, 1989). There is no information available on how temporal variations in extreme.

Climate under irrigated aridisols of Western Rajasthan with respect to differential irrigation treatments. Hence, the study was undertaken to examine the gas exchange characteristics of Kinnow mandarin under drip irrigation system. Kinnow mandarin is grown under canal command areas of irrigated parts of North Western Rajasthan state. It is inevitable that any deficiency of water particularly during critical stages after fruit set in mandarin results in drastic reduction in dry matter and leads to significant low yield biomass. The relationship between weather parameters and month wise periodical changes in photosynthesis concurrent with water use efficiency and their interrelationships were not studied in Kinnow mandarin. In the present study, emphasis is laid on the month wise variation in photosynthetic parameters in relation to weather conditions and interrelationship in drip irrigation system at three irrigation treatments based on evapotranspiration coefficient.

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Material and methods

Kinnow mandarin plants (2 years old after field planting) at 6x6 m budded on *Citrus jambhiri* were selected for study under drip irrigation system at the experimental site of Agriculture Research Station, SriGanganagar. These plants were grown in alluvial soils of sandy loam texture under drip system at 40, 70 and 100% evapotranspiration coefficient and have receive recommended doses of fertilisers. The irrigated Kinnow plants were watered continuously for a week as per irrigation scheduling prior to measurements. A total of twenty one Kinnow plants were taken for experimental study. Measurements on gas exchange characteristics under drip system (7 plants treatment^{-1}) were simultaneously taken during the day (8-10 am) from April 2002 to December 2004 successively for three years Vis a Vis 40, 70 and 100 % Etc treatments. With the initiation of new ambe bahar growth of Kinnow plants in March, the experimental observations were recorded from April to December month's i.e. the active growth period from flowering to fruiting cycle. Photosynthesis (A), stomatal conductance (g_s), substomatal CO_2 concentration (c_i), transpiration (E), photo synthetically active radiation (PAR) incidence on the leaf surface and leaf surface temperature were recorded using a ADC photosynthesis system (Model LCA 4, ADC, UK). Before the use of instrument, zero settings for H_2O and CO2 made. The boundary layer resistance to vapour was typically 0.8 $m^2s^{-1}mol^{-1}$. Air was drawn into the instrument from an air probe at the height of 3m above ground surface. The air pumped into the system was dried using anhydrous calcium sulphate. The gas flow to leaf chamber was maintained at 300±2μ mols^{-1}. The experimental area under drip and micro-sprinkler system of irrigation at the completion of two years(2003) came into bearing profusely and initially it was decided that the fruit of this year will be retained so the flowers were subjected to drop but while doing so re thought was given and finally decided to remove the flowers in half of the replications completely and in rest 50 per cent flowers were retained so as to see the impact of fruit bearing on the overall growth of the tree in all the three treatments in comparison to other Kinnow plants.

Results and discussion

The results in table-1 clearly elucidates that after onset of spring in the month of April maximum photosynthesis A(4.84) was recorded in 70% Etc treatment with a minimum of substomatal concentration c_i (101.10) in correlation with highest Stomatal conductance g_s (0.03) and maximum transpiration (1.45) rate as compared to 40 and 100% Etc treatments. The reason for this might be due to minimum stomatal resistance r_s in 70% Etc treatment with respect to 40 and 100% Etc treatment. The low photosynthesis in higher irrigation treatment 100% Etc might be attributed to increase in leaf temperature which results in damage to photosynthetic apparatus irrespective of the fact that water use efficiency was higher(3.82) under 100% Etc treatment as compared to 70% treatment. Low assimilation rates of citrus are accompanied by low rates of transpiration and extreme sensitivity to moisture deficit (Kriedemann and Barrs, 1981).

The data in table-2 revealed that in the month of May, highest photosynthetic rate A for Kinnow plants (6.28) was observed in 70% Etc treatment along with maximum transpiration rate.

The higher photosynthetic rate in 70% Etc treatment might be due to better partitioning of assimilates in this treatment coupled with higher stomatal conductance (0.08) and minimum stomatal resistance (15.80) with respect to 40 and 100% Etc treatments. The perusal of data in table-3 for June depicts an increasing trend of carboxylation efficiency of Kinnnow plants with respect to differentially increasing irrigation treatments being maximum in 100% treatment. Higher assimilation rate of Kinnow in May reflects the special genetic character of this citrus species that how well it is acclimatized in the extremes of irrigated aridisols with the saturation of photosynthesis at high light intensities. This might be due to the fact that water use efficiency was highest (2.78) in conjunction with lowest transpiration rate in 100% Etc treatment as compared to 40 and 70% treatments.

The data in table-4 for July depicted that maximum carboxylation efficiency of Kinnow (6.70) was recorded in 70% etc treatment and exhibited a significant increase in A as compared to 40 and 70% Etc treatments. The reason for this might be due to better uptake and utilization of water i.e. highest water use efficiency (2.58) was recorded in 100% Etc treatment which was significantly better than 40 and 70% treatments. The results of present findings are in accordance with those of (Sinclair and Allen, 1982) that better photosynthetic rates of citrus are attained at low PAR intensities. The data in table-5 for August depicted that highest photosynthate partitioning of Kinnow was recorded in 100% Etc treatment which showed a positive correlation with stomatal conductance and transpiration despite lowest water use efficiency as compared to 40 and 70% treatments.

The low PAR intensities recorded in all the three irrigation treatments are due to cloud effect at the time of recording of observations. The results are in conformity with the findings of (Vu and Yalenosky, 1988) that photosynthetic rates of citrus saturates at relatively low light intensities i.e. about 30% of full sunlight in outer parts of the tree canopy.

Table 1. Physiological parameters during April (2002-04)

Variable	Drip (per cent Etc) 40	70	100	C.D. at 5%
Photosynthetic Rate ($A=mmolm^{-2}s^{-1}$)	2.71	4.84	3.67	0.908
Stomatal conductance ($gs=m^2smol^{-1}$)	0.01	0.03	0.02	N.S.
Stomatal resistance ($g_s=rsm^2smol^{-1}$)	67.11	32.60	56.14	14.01
Leaf Temperature(°C)	38.33	39.39	40.28	N.S.
Transpiration rate $E=molm^{-2}s^{-1}$)	0.68	1.45	0.96	0.252
Sub-Stomatal CO_2 concentration	122.10	101.10	101.30	N.S.
Photosynthetic Active Radiation ($Q= mmolm^{-2}s^{-1}$)	1840.66	1899.66	1749.66	N.S.
Relative Humidity (R.H.= %)	45.96	41.96	41.03	N.S.
Water Use Efficiency	3.98	3.33	3.82	N.S.

Table 2. Physiological parameters during May (2002-04).

Variable	Drip (per cent Etc) 40	70	100	C.D. at 5%
Photosynthetic Rate ($A=mmolm^{-2}s^{-1}$)	4.39	6.28	5.59	1.31
Stomatal conductance ($gs=m^2smol^{-1}$)	0.05	0.08	0.05	0.01
Stomatal resistance ($g_s=rsm^2smol^{-1}$)	18.92	15.80	19.26	N.S.
Leaf Temperature(°C)	39.29	38.94	38.27	N.S.
Transpiration rate $E=molm^{-2}s^{-1}$)	2.52	3.43	2.41	0.71
Sub-Stomatal CO_2 concentration	228.52	202.50	189.3	N.S.
Photosynthetic Active Radiation ($Q= mmolm^{-2}s^{-1}$)	1137.60	1175	1093.2	N.S.
Relative Humidity (R.H.= %)	18.08	18.40	16.98	N.S.
Water Use Efficiency	1.74	1.83	2.31	N.S.

Table 3. Physiological parameters during June (2002-04)

Variable	Drip (per cent Etc) 40	70	100	C.D. at 5%
Photosynthetic Rate ($A=mmolm^{-2}s^{-1}$)	4.49	4.71	4.79	N.S.
Stomatal conductance ($gs=m^2smol^{-1}$)	0.07	0.05	0.03	0.01
Stomatal resistance ($g_s=rsm^2smol^{-1}$)	15.16	18.69	28.59	4.73
Leaf Temperature(°C)	39.50	39.32	39.5	N.S.
Transpiration rate $E=molm^{-2}s^{-1}$)	3.15	2.54	1.72	0.69
Sub-Stomatal CO_2 concentration	225.74	203.32	134.66	51.83
Photosynthetic Active Radiation ($Q=mmolm^{-2}s^{-1}$)	1137.4	1106.2	1103.4	N.S.
Relative Humidity (R.H.= %)	19.42	19.46	19.10	N.S.
Water Use Efficiency	1.42	1.85	2.78	1.22

Table 4. Physiological parameters during July (2002-04)

Variable	Drip (per cent Etc) 40	70	100	C.D. at 5%
Photosynthetic Rate (A=mmolm^{-2}s^{-1})	3.30	6.70	5.76	1.22
Stomatal conductance (g$_s$=m^{2}smol^{-1})	0.18	0.09	0.11	0.03
Stomatal resistance (g$_s$=rsm^{2}smol^{-1})	6.73	11.87	11.74	2.32
Leaf Temperature(°C)	38.16	36.59	38.05	N.S.
Transpiration rate E=molm^{-2}s^{-1})	3.82	2.59	3.03	0.83
Sub-Stomatal CO_2 concentration	326.8	233.38	252.48	72.14
Photosynthetic Active Radiation (Q= mmolm^{-2}s^{-1})	1264.2	928.0	1314.2	297.03
Relative Humidity (R.H. = %)	25.20	26.48	27.46	N.S.
Water Use Efficiency	0.86	2.58	1.90	0.41

Table 5. Physiological parameters during August (2002-04)

Variable	Drip (per cent Etc) 40	70	100	C.D. at 5%
Photosynthetic Rate (A=mmolm^{-2}s^{-1})	7.25	6.89	7.93	N.S.
Stomatal conductance (g$_s$=m^{2}smol^{-1})	0.06	0.04	0.07	0.01
Stomatal resistance (g$_s$=rsm^{2}smol^{-1})	17.72	27.92	13.80	1.36
Leaf Temperature (°C)	34.23	34.53	34.59	N.S.
Transpiration rate E=molm^{-2}s^{-1})	1.39	1.04	1.72	0.34
Sub-Stomatal CO_2 concentration	124.82	122.68	173.58	33.63
Photosynthetic Active Radiation (Q= mmolm^{-2}s^{-1})	500.0	469.2	672.8	132.09
Relative Humidity (R.H. = %)	26.92	27.22	27.66	N.S.
Water Use Efficiency	5.21	6.62	4.61	1.42

Table 6. Physiological parameters during September (2002-04)

Variable	Drip (per cent Etc) 40	70	100	C.D. at 5%
Photosynthetic Rate (A=mmolm^{-2}s^{-1})	2.48	2.53	3.15	N.S.
Stomatal conductance (g$_s$=m^{2}smol^{-1})	0.05	0.05	0.03	0.01
Stomatal resistance (g$_s$=rsm^{2}smol^{-1})	20.03	20.81	25.80	N.S.
Leaf Temperature(°C)	33.74	33.67	34.03	N.S.
Transpiration rate E=molm^{-2}s^{-1})	1.20	1.20	1.01	N.S.
Sub-Stomatal CO_2 concentration	255.50	277.17	207.82	N.S.
Photosynthetic Active Radiation (Q= mmolm^{-2}s^{-1})	951.50	959.25	985.00	N.S.
Relative Humidity (R.H. = %)	50.77	50.92	51.00	N.S.
Water Use Efficiency	2.06	2.10	3.11	0.57

The data in table-6 for September revealed that highest photosynthetic rate of Kinnow was recorded in 100% Etc treatment which showed a positive correlation with comparative best water use efficiency as compared to 40 and 70% treatments. The low photosynthetic rates in all the three irrigation treatments in the month of September as compared to previous months are accompanied by low rates of transpiration and extreme sensitivity to soil moisture deficit and also due to translocation of assimilates from source to sink thereby having an impact of first bearing on the overall growth of the tree. These findings are in agreement with those of Kriedemann and Barrs, (1981) who reported that low assimilation rates of citrus are due to low substomatal concentration. The data in table-7 for October revealed that maximum carboxylation efficiency of Kinnow was estimated in 100% Etc treatment as compared to 40 and 70% irrigation treatments. The better A in 100% treatment might be due to increased stomatal conductance and maximum water use efficiency with respect to other treatments. The low photosynthetic rates in 40 and 70% Etc levels indicate the limitation of photosynthetic rates at the mesophyll level.

The data in table-8 for the month of November revealed that maximum assimilation of carbohydrates in Kinnow was recorded in 70% Etc treatment which showed a positive correlation with maximum water use efficiency in the same treatment coupled with lowest transpiration Vis a Vis 40 and 70% treatment. At low relative humidity, the transpiration reduced due to decrease in evapotranspiration driving forces.

The data in table-9 for the month of December depicted that highest photosynthetic rate was attained in 70% treatment which exhibited a positive correlation with

Table 7 Physiological parameters during October (2002-04)

Variable	Drip (per cent Etc)			
	40	70	100	C.D. at 5%
Photosynthetic Rate (A=mmolm^{-2}s^{-1})	1.28	2.02	2.50	0.43
Stomatal conductance (g_s=m^{2}smol^{-1})	0.05	0.07	0.08	0.01
Stomatal resistance (g_s=rsm^{2}smol^{-1})	17.07	13.55	12.35	N.S.
Leaf Temperature (°C)	33.39	33.42	33.83	N.S.
Transpiration rate E=molm^{-2}s^{-1})	1.87	2.22	2.50	N.S.
Sub-Stomatal CO_2 concentration	323.1	314.32	306.40	N.S.
Photosynthetic Active Radiation (Q= mmolm^{-2}s^{-1})	954	920	990.66	N.S.
Relative Humidity (R.H. = %)	29.55	30.62	32.33	N.S.
Water Use Efficiency	0.68	0.90	1.00	0.20

Table 8. Physiological parameters during November (2002-04)

Variable	Drip (per cent Etc)			
	40	70	100	C.D. at 5%
Photosynthetic Rate (A=mmolm^{-2}s^{-1})	3.84	3.71	3.53	N.S.
Stomatal conductance (g_s=m^{2}smol^{-1})	0.05	0.05	0.06	N.S.
Stomatal resistance (g_s=rsm^{2}smol^{-1})	18.01	19.21	16.71	N.S.
Leaf Temperature(°C)	30.55	29.73	27.26	N.S.
Transpiration rate (E=molm^{-2}s^{-1})	1.65	1.51	1.53	N.S.
Sub-Stomatal CO_2 concentration	257.74	274.65	286.05	N.S.
Photosynthetic Active Radiation (Q= mmolm^{-2}s^{-1})	1259.0	1358.66	1165.83	N.S.
Relative Humidity (R.H. = %)	25.60	25.96	27.80	N.S.
Water Use Efficiency	2.32	2.45	2.30	N.S.

Table 9. Physiological parameters during December (2002-04)

Variable	Drip (per cent Etc)			
	40	70	100	C.D. at 5%
Photosynthetic Rate ($A=mmolm^{-2}s^{-1}$)	2.84	4.41	4.11	0.89
Stomatal conductance ($g_s=m^2smol^{-1}$)	0.09	0.14	0.12	0.02
Stomatal resistance ($g_s=rsm^2smol^{-1}$)	11.12	7.264	8.041	2.38
Leaf Temperature(°C)	27.17	26.72	24.50	N.S.
Transpiration rate ($E=molm^{-2}s^{-1}$)	1.84	2.53	2.04	N.S.
Sub-Stomatal CO_2 concentration	313.61	319.66	320.88	N.S.
Photosynthetic Active Radiation ($Q=mmolm^{-2}s^{-1}$)	717.00	1122.55	936.87	224.26
Relative Humidity (R.H. = %)	30.60	28.66	29.47	N.S.
Water Use Efficiency	1.54	1.74	2.01	N.S.

maximum stomatal conductance (0.14) value and minimum stomatal resistance as compared to 40 and 100% treatments. The better stomatal conductance in all the three treatments is predominantly influenced by low leaf temperature during the month of December. Fig1 to 5 shows the occurrence of cyclic oscillations in photosynthesis, stomatal conductance, stomatal resistance, transpiration rate and photosynthetic active radiation under field conditions.

The data in table-10 revealed that during first bearing highest number of fruits (38.13) was recorded in 70% Etc which was significantly higher than 40 and 70% Etc treatments. The better fruit retention under 70% Etc might be due to better carboxylation efficiency, good stomatal conductance and minimum stomatal resistance as compared to 40 and 70% Etc treatments.

Table-10. Fruit retention per tree under different levels of drip irrigation system

S.No.	Irrigation level	Drip System(2003-04)
1.	40% Etc	30.85
2.	70% Etc	38.13
3.	100% Etc	28.37
	Mean	32.45

References

Flore, J.A. and Lakso, A.N. 1989. Environmental and physiological regulation of photosynthesis in fruit crops; *Hortic Rev.* 11:111-157.

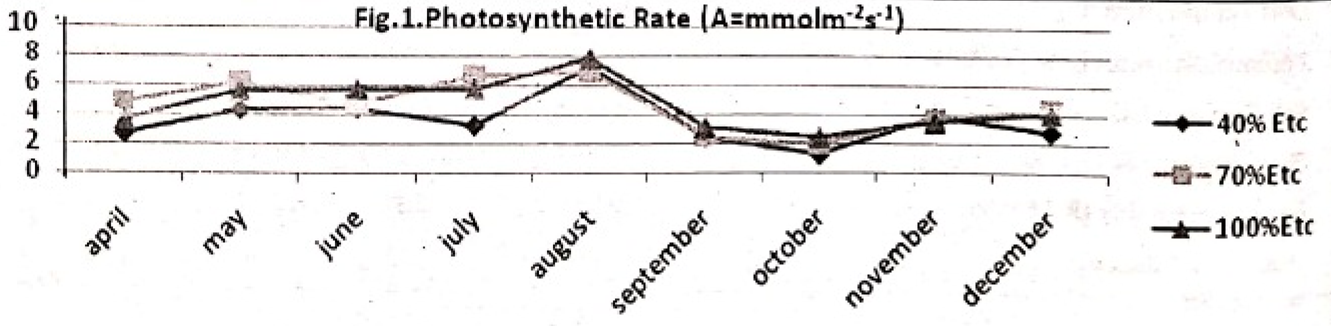
Maroco J.P, Pereira J.S and Manuela Chaves M. 1997. Stomatal response to leaf to air vapour pressure deficit in Sahelian species; *Aust J Plant Physiol.* 27:381-387.

Kriedemann, P.E. and Barrs, H.D. 1981. Citrus orchards. In water Deficits and Plant Growth. Vol.6, ed. T.T. Kozlowski, pp: 325-417.

Sinclair, T.R. and Allen, L.H. Jr. 1982. Carbon dioxide and water vapour exchange of leaves on field grown citrus trees. Journal of Experimental Botany. 33:1166-1175.

Vu, J.C.V. and Yelenosky, G. (1988). Solar irradiance and drought stress effects on the activity and concentration of ribulose biphosphatase carboxylase in 'Valencia' oorange subjected to water deficits. Environ. Expt. Bot., 29:149-154.

Fig.1.Photosynthetic Rate ($A=mmolm^{-2}s^{-1}$)



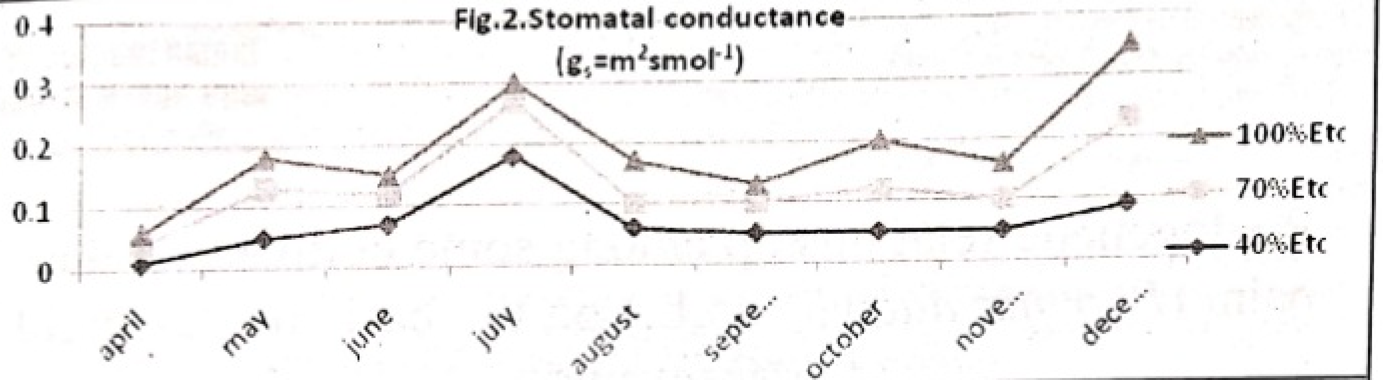


Fig.2.Stomatal conductance (g_s=m^2smol^{-1})

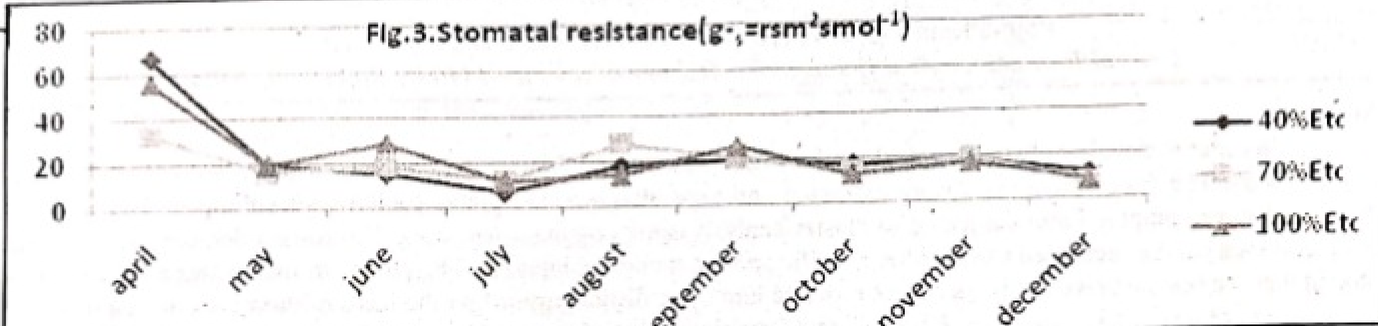


Fig.3.Stomatal resistance(g^{-}_s=rsm^2smol^{-1})

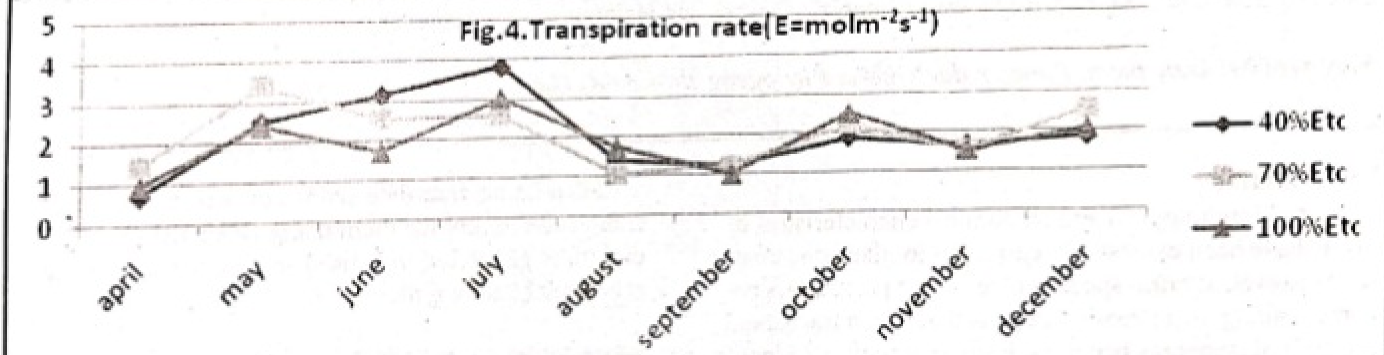


Fig.4.Transpiration rate(E=$molm^{-2}s^{-1}$)

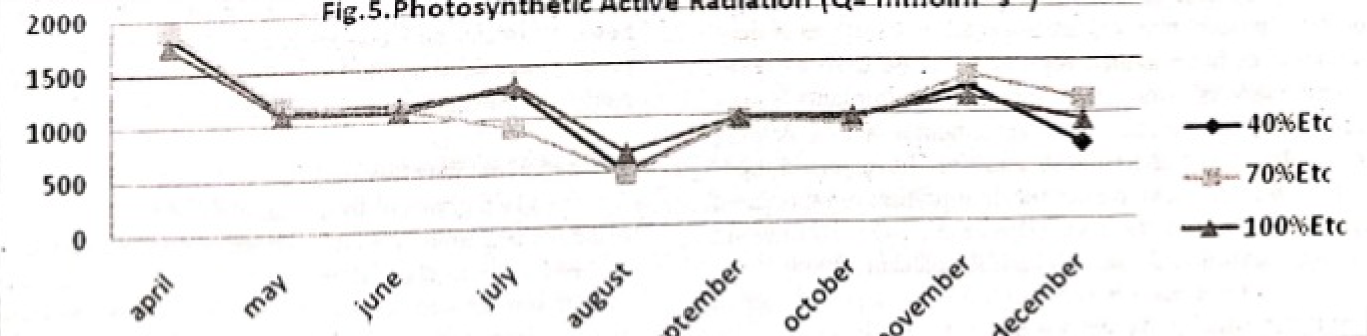


Fig.5.Photosynthetic Active Radiation (Q= $mmolm^{-2}s^{-1}$)

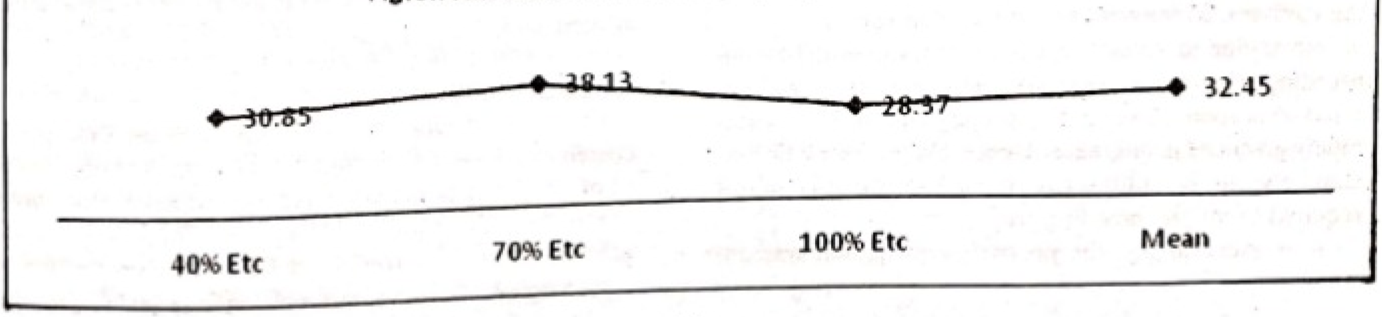


Fig.6.Fruit retention under drip system (2003-04)