RESEARCH ARTICLE

PHYSIOLOGICAL STUDIES OF DIFFERENT CITRUS SPECIES AND THEIR CULTIVARS UNDER SEMI-ARID CONDITIONS OF HISAR, (HARYANA)

Nidhi Sharma*, Savita Duhan, Suneel Sharma and K.D. Sharma

Department of Horticulture,
Department of Botany and Plant physiology,
ChaudharyCharan Singh Haryana Agriculture University,
Hisar, Haryana-125004, India
Email:nidhi.nandani@gmail.com

Received-05.03.2017, Revised-24.03.2017

Abstract: The experiment on well-maintained 12 year old trees each of Sweet orange (C*itrus sinensis*(L.)Osbeck) *cv.* Jaffa and Pineapple; Mandarin hybrids Pearl Tangelo *(Citrus reticulata*Blanco *x Citrus paradisi*Macf.) and Kinnow *(Citrus nobilis* Lour. x *Citrus deliciosa*Tenore) and Grapefruit (C*itrus paradisi*Macf.)*cv.*Duncan and Ruby Red was carried out at CCS HAU, Hisar during 2014 and 2015. The relative water contentwere observed 80-90% in almost all cultivars. Cell membrane stability index and potent physiological indices were observed highest in Kinnow. As Kinnow mandarin was found most photo-synthetically efficient mandarin cultivar in fixing more CO_2 among all cultivars and species of citrus. Transpiration rate was recorded highest in sweet orange cv. Pineapple and lowest in grapefruit cv. Duncan. Apparently no marked differences were recorded in stomatal conductance among all citrus species and their cultivars. Leaf water potential in Pineapple and osmotic potential in cv. Ruby Red were greatest.Whereas it was lowest in grapefruit cv. Ruby Red and osmotic potential in sweet orange cv. Jaffa.Spring flush leaves of Kinnow mandarin were behaved most drought tolerant with least cell membrane injury, followed by Ruby Red grapefruit with highest cell membrane stability index.

Keywords: Citrus, Mandarin, Sweet orange, Grapefruit, Cell membrane injury

INTRODUCTION

Citrus, belongs to C_3 plants, with photosynthetic rates lower than rate of C_4 plants. It is economically most important fruit crop of the world, is grown in both developed and developing countries and certainly constitutes one of the main sources of vitamin C. It contains the largest number of carotenoids found in any fruit with an extensive array of secondary compounds such as vitamin E, provitamin A, flavonoids, limonoids, polysaccharides, lignin, fiber, phenolic compounds and essential oils etc. having pivotal nutritional properties (Iglesias *et al.*, 2007). The citrus grows under rather varied climatic conditions, ranging in latitude from over 40° north to almost 40° south, from equatorial hot-humid climates through the warm-subtropical and even cooler maritime climates (Spiegel-Roy and Goldschmidt, 1996). It is a commercially vital fruit crop of India and grown across its length and breadth with a production of 111.47 thousand MT from an area of 1077.7 thousand hectares (Saxena and Gandhi, 2015)

There are marked differences in growth pattern of different citrus species.Mediavilla*et al.* (2001) reported that plants leaf photosynthetic rate depends on photosynthetic components contents, such as RuBisCO, cytochromef, H+-ATPase and reaction centers, but also on structural parameters, such as leaf thickness and area per leaf mass. Morinaga and Sykes (2001) reported that photosynthesis of Satsuma Mandarin decrease when water potential decrease below -1.5 MPa. The inhibition of net photosynthesis under water stress may result in part from lower diffusion of CO_2 across the leaf mesophyll cells (Flexas and Medrano, 2002). Stomatal limitations play an important role in the down regulation of sweet orange tree photosynthesis under heat stress conditions. Jifon and Syvertsen(2003) concluded that there is a direct effect of high temperature on citrus leaf photosynthesis due to which stomatal conductance reduced. Stomata in species of citrus are confined to the ventral surface of the leaves and density of stomata decreased as the area of the leaf increased. The size of stomata in *Citrus* leaves varies among species. Kriedemann and Barras (1981) reported low stomatal conductance in Sweet orange < 8 µmol CO_2 m^{-2} s^{-1}. Citrus leaf stomatal conductance (*g*s) is particularly sensitive to changes in leaf to air vapour pressure difference; stomatal conductance decreases as leaf temperature leaf to air vapour pressure differenceincrease (Syvertsen and Salyani, 1991). This enable trees to limit water loss, and thereby increase water-use efficiency and productivity in semi-arid environments.

As per Mendel (1969) the main temperature ranges for the growth of citrus is minimum of 12.5-13 ^{o}C optimum, 23-34 ^{o}C and maximum (limiting growth) 37-39 ^{o}C. Thus, in central India month of March is found crucial for citrus growth. In this period minimum temperature remains favorable for growth, but maximum exceeds beyond required limit and cause heavy drop of small fruitlets and leads to drastic reduction in yield. The low nocturnal temperature inhibit photosynthesis by decreasing

*Corresponding Author

RuBP carboxylation and the maximum electron transport rate for RuBP regenerationwith impairment of primary photochemistry under 38 ºC. Citrus respiration is also affected by temperature being stimulated in leaf temperatures higher than 35 ºC (Ribeiro*et al.*, 2012) thus affect pheno-physiological characteristics of citrus. Ribeiro*et al*. (2008) found the higher temperature and low relative humidity induce decreases in leaf water potential, stomatal conductance and leaf CO_2 assimilation of exposed leaves. They may reduce carbohydrate synthesis and the supply to reproductive sinks, being a cause of intense drop of flowers and fruits.

The significant correlations of leaf water potential, leaf relative water content, and leaf osmotic potential with protein content and Rubisco under severe stress, revealed a close relationship of these parameters on recovery. Lower cellular osmotic potentials also conserve cellular volume and maintain gradients of water potential favorable for water influx (Mediavilla*et al.*, 2001). Cell membrane injury reflects damage to cell membranes. Srinivasan*et al.* (1996) suggested that damage to cell membranes (as reflected by an increased leakage of electrolytes) was less, and recovery from heat stress was faster thus membrane injury was negatively associated with specific leaf weight.

No work has been done to study the growth and fruiting patterns in Citrus species and cultivars under semi-arid conditions of Haryana. Therefore, present investigation entitled ‘Physiological studies of different *Citrus* species and cultivars under semi-arid conditions of Hisar, Haryana’ was planned with the following objectives:To study the growth pattern and physiological indices in citrus species

MATERIAL AND METHOD

Fully grown and properly maintained of uniform size and vigour, free from disease and pest, twelve year old trees involving three *Citrus* groups with two cultivars in each were used in study. For all the six varieties of three groups, the spring flush was taken for the investigation.

1. Sweet orange (C*itrus sinensis*(L.) Osbeck) *cv.* Jaffa and Pineapple
2. Mandarin hybrids- Pearl Tangelo *(Citrus reticulata*Blanco *x Citrus paradisi*Macf.) and Kinnow *(Citrus nobilis* Lour. x *Citrus deliciosa* Tenore)
3. Grapefruit (C*itrus paradisi*Macf.)*cv.*Duncan and Ruby Red

Five trees of each of two cultivars taken from every species mentioned above three citrus groups were selected for investigation. Thus, all the six cultivars were replicated five times using single plant as a unit arranged in Randomized Block Design (RBD). The recommended standard package of cultural practices and plant protection measures for citrus crop were followed uniformly for all these 30 trees throughout the study period. On each replicated tree, randomly five shoot were tagged in all directions representing North, West, East and South and middle portion of the tree canopy for further recording following observations.

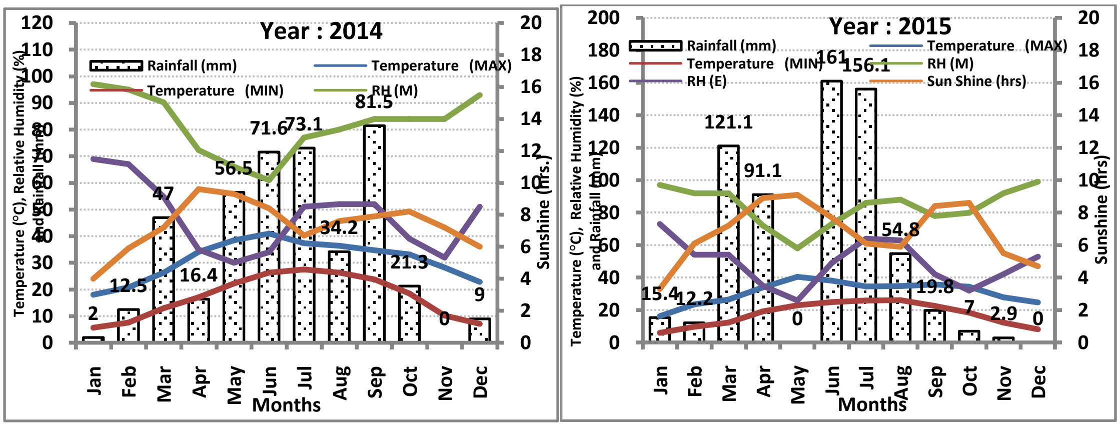

Figure 1. The graphical presentation of meteorological parameters recorded at experimental orchard site Hisar during the year 2014 and 2015.

Photosynthetic rate(μmol/m^2/sec): Five matured leaves were selected on each plant in lot of five and their photo synthetic rates were measured using infrared gas analyzer (PS System II) and average photosynthetic rate was expressed inμ mol/m^2/sec.Transpiration rate and stomata conductance (m mol/m^2/sec): Five matured leaves were selected on each plant in lot of five and their transpiration rate and stomata conductance were measured using infrared gas analyzer and average transpiration rate and stomata conductance was expressed in m mol/m^2/sec.Leaf water potential (bars): In a transpiring plant, water in the xylem is pulled upward by transpirational pull and hence the xylem water column is under tension, the tension with which the xylem sap is pulled towards the leaf cells is equal to the potential of the leaf cells.Leaf osmotic potential (bars):The osmotic potential or solute potential (ψ_s) of a system, measured by Osmometer, can be defined as the amount of work that must be done per unit quantity of pure water to transport it reversibly from a pool of pure water at a specified elevation at atmospheric pressure, to a pool containing a solution identical in composition with the water of the system under consideration otherwise identical to the reference pool. It is equal and negative to osmotic pressure (ψ_s = - π). Five leaves per plant were collected from experimental field at the time of fruit set. Leaf samples freezed at -70°C were taken out and allow it to thaw. Then took sap from the sampled tissue. Opened the sample chamber of osmo-meter and loaded 10 μL of the sap onto the sample disc. Inserted sample slide and closed the sample chamber by rotating the chamber locking lever to the horizontal 'locked' position. Read out the osmolality at end of the process. Leaf relative water content (%): The relative water content in recently matured leaves was determined as per method of Brass and Weathery (1962). In order to reduce the chances of water loss from leaves, the leaf samples wrapped and sealed properly in polythene bags were brought to the lab as soon as possible. Collected leaves were immediately rinsed with distilled water and cut into 8 mm discs with a cork borer. A composite sample of 10 leaf discs was made with a disc cutter and fresh weight of the discs made was determined, followed by flotation on double-distilled water in closed petri-plates for 4 h. The turgid weight was then recorded after surface drying by placing then in between few sheets of Whatman No.1 filter papers. These leaf discs were then placed for drying in oven at 70°C for 2 to 3 days until constant weight. Finally the dry weight (DW) of samples was recorded. The relative water content was estimated using the following formula.

LRWC (%) = [(Fresh weight – oven DW) / (Turgid weight – oven DW)] x 100

Cell membrane injury and stability indexes (CMII): The method suggested by Blum and Ebercon (1981) was employed for the estimation of membrane injury index of leaf. Accurately weighed 0.1 g of freshly sampled leaf material was immersed in a test tube containing 10 ml of double distilled water. The tube was incubated at 45°C for 30 minutes in a hot water bath. Thereafter, electrical conductivity of the incubated solution (EC1) was measured with the help of a conductivity meter (Systronics India Ltd., Mumbai, India). These tubes were then incubated in hot water bath (100°C) for a period of 10 minutes. The incubated solution was cooled down to the room temperature and electrical conductivity (EC2) was measured. The membrane injury index of leaf was calculated according to the following formula.

Cell membrane injury (CMII) = EC1/EC2

RESULT AND DISCUSSION

Photosynthesis, transpiration and stomatal conductance rates

The photosynthetic rate was found maximum in Kinnow (6.74 and 6.10 µmol/m^2/sec) and minimum in Pearl Tangelo (3.52 and 3.37 µmol/m^2/sec) during both the years. Data mentioned in Table 1 indicated that photosynthetic rate of sweet orange and grapefruit was almost at par with each other during all phenological stages. This indicated that Kinnow was photo-synthetically most efficient cultivar in fixing higher CO_2 among all cultivars. The rate of transpiration reveals the extent of gaseous exchange in plants. Maximum rate of transpiration was recorded in sweet orange cv. Pineapple (2.17 and 2.14 m mol/m^2/sec) while, minimum transpiration in grapefruit cv. Duncan (1.80 and 1.76 m mol/m^2/sec) in respective two years of study (Table 1).

Table 1. Rate of photosynthesis, transpiration and stomatal conductance in different citrus species and cultivars during 2014 and 2015

Citrus species	**Cultivars**	**Season 2014**		
		Photosynthesis rate (µmol/m^2/sec)	**Transpiration rate (m mol/m^2/sec)**	**Stomatal conductance rate (m mol/m^2/sec)**
Sweet orange (*Citrus sinensis*)	Jaffa	5.39	2.11	49.60
	Pineapple	4.33	2.17	46.80
Mandarin hybrids	Pearl Tangelo	3.52	2.12	44.40
	Kinnow	6.74	1.87	45.70
Grapefruit (*Citrus paradisi*)	Duncan	5.60	1.80	46.30
	Ruby Red	5.86	1.84	41.30
Mean		5.24	1.98	45.68
SE(m)±		0.43	0.08	2.67
CD at 5%		1.23	0.23	N.S.
Citrus species	**Cultivars**	**Season 2015**		
Sweet orange (*Citrus sinensis*)	Jaffa	5.47	2.05	54.20
	Pineapple	4.38	2.14	48.00
Mandarin hybrids	Pearl Tangelo	3.37	2.09	45.80

	Kinnow	6.10	1.84	47.40
Grapefruit (*Citrus paradisi*)	Duncan	5.47	1.76	48.70
	Ruby Red	5.81	1.78	44.40
Mean		5.10	1.94	48.08
SE(m)±		0.32	0.06	2.53
CD at 5%		0.91	0.17	N.S.

The stomatal conductance rate was highest in sweet orange cv. Jaffa (49.60 and 54.20 m mol/m^2/sec) and minimum in grapefruit cv. Ruby Red (41.30 and 44.40 m mol/m^2/sec) in both the years (Table 1). Apparently no marked differences in the stomatal conductance were noted among all the citrus species and cultivars/hybrids during both the years of investigation.

Leaf water potential and leaf osmotic potential (-MPa)

Leaf water potential is an important aspect to estimate the effect of water status of characteristic young spring flush leaves of citrus on flowering and fruit set. Young citrus leaves tend to have lower leaf water potentials. During summers, the stressed new leaves attain zero turgor with higher leaf water potentials. Thus, data given in Table 2 showed significant differences in leaf water potential of various citrus species and cultivars investigated. Highest leaf water potential was recorded in sweet orange cv. Pineapple (1.38 and 1.44 -MPa) and lowest was in grapefruit cv. Ruby Red (1.65 and 1.60 -MPa) during both the years.

New leaves of spring flush had higher osmotic potential then older leaves, which became non-significant as leaves attained maturity (Table 2). The higher leaf osmotic potential recorded in grapefruit cv. Ruby Red. (1.51and 1.85 -MPa) revealed the tendency or capability of grapefruits leaves to adjust them osmotically under stress environment. While, leaves of sweet orange cv. Jaffa had least osmotic potential (1.95 and 1.81-MPa) to be true as the reverse and hence, least adjusting under stress environmental conditions. The mandarins appeared to be intermediate of both the sweet orange and grapefruits for this parameter.

Cell Membrane Injury (%)

Cell membrane injury (CMI) is a stress analyzing factor and its maximum value CMI indicates the sensitivity of plant towards stressed conditions. Data presented in Table 2 indicated noticeable differences in CMI of spring flush leaves of various species and their cultivars till the time of fruit set. Mandarin hybrid Kinnow was found tolerant to stress with minimum CMI values of 25.54 and 33.15% in both the years. Whereas, grapefruit cv. Duncan was found most sensitive in stress tolerance throughout the study with maximum CMI values of 44.70 and 44.81%. Other cultivars were at par with mandarin hybrid Kinnow. Statistically, there were significant differences in CMI among different cultivars during both years.

Table 2. Physiological indices in different citrus species and cultivars during 2014 and 2015

Citrus species	**Cultivars**	**Season 2014**		
		Membrane injury (%)	**Leaf water potential (-MPa)**	**Leaf osmotic potential (-MPa)**
Sweet orange (*Citrus sinensis*)	Jaffa	39.97	1.39	1.95
	Pineapple	32.01	1.38	1.86
Mandarin hybrids	Pearl Tangelo	30.76	1.57	1.71
	Kinnow	25.54	1.48	1.65
Grapefruit (*Citrus paradisi*)	Duncan	44.70	1.57	1.75
	Ruby Red	28.47	1.65	1.51
Mean		33.58	1.74	1.51
SE(m)±		0.52	0.15	0.05
CD at 5%		1.49	N.S.	0.13
Citrus species	**Cultivars**	**Season 2015**		
Sweet orange (*Citrus sinensis*)	Jaffa	44.01	1.57	1.75
	Pineapple	41.10	1.44	1.75
Mandarin hybrids	Pearl Tangelo	37.71	1.58	1.73
	Kinnow	33.15	1.49	1.66
Grapefruit (*Citrus paradisi*)	Duncan	44.81	1.59	1.75
	Ruby Red	36.66	1.60	1.81
Mean		39.57	1.74	1.55
SE(m)±		1.42	0.04	0.05
CD at 5%		3.52	N.S.	N.S.

Relative water content (%)

Leaf relative water content (RWC) is a measure of plant water status of which the data is presented in Tables 3a and 3b. It showed a significant decrease while moving towards stress period of the year (March to July), then slight increase in relative water content was observed in all species towards end of year. The mean RWC content within species was recorded maximum in cv. Pineapple followed by Jaffa.

Table 3a. Relative water content (%) in different citrus species and cultivars at different growth stages during 2014 till fruit harvest

Month of observation	Relative water content (%) during 2014					
	Sweet orange		Mandarin hybrids		Grapefruit	
	Jaffa	Pineapple	Pearl Tangelo	Kinnow	Duncan	Ruby Red
March	85.52	85.72	85.95	85.41	85.41	85.26
April	84.64	85.62	85.51	83.47	84.00	84.98
May	84.28	85.26	84.80	82.16	83.88	83.43
June	77.70	78.68	77.26	79.40	80.81	78.85
July	79.58	81.60	79.31	81.91	81.30	80.82
August	81.88	83.64	85.81	82.24	82.88	81.48
September	83.64	85.13	85.94	83.82	83.12	82.95
October	84.22	86.94	-	85.86	84.15	84.93
November	85.09	87.78	-	84.37	85.07	85.73
December	-	-	-	85.76	-	-
Mean	82.95	84.48	83.51	83.44	83.40	83.16
SE(m)±	0.81	2.46	1.62	1.55	0.89	0.67
CD at 5%	2.34	N.S.	4.76	N.S.	1.82	1.93

Table 3b. Relative water content (%) in different citrus species and cultivars at different growth stages during 2015 till harvest

Month of observation	Relative water content (%) during 2015					
	Sweet orange		Mandarin hybrids		Grapefruit	
	Jaffa	Pineapple	Pearl Tangelo	Kinnow	Duncan	Ruby Red
March	85.33	86.70	86.64	85.74	84.92	86.20
April	84.76	85.15	85.25	84.97	85.86	85.11
May	83.91	83.87	83.98	83.48	85.31	83.79
June	83.40	84.04	83.99	83.49	85.11	84.88
July	83.86	84.21	84.22	83.67	84.82	85.45
August	84.60	84.83	85.09	84.42	84.62	84.95
September	84.46	85.24	85.53	84.88	85.61	85.89
October	85.38	85.54	-	84.91	85.87	85.57
November	85.72	85.81	-	85.20	85.90	85.08
December	-	-	-	85.97	-	-
Mean	84.60	85.04	84.96	84.67	85.33	85.21
SE(m)±	1.84	0.64	0.58	0.95	0.61	0.86
CD at 5%	N.S.	N.S.	1.69	N.S.	N.S.	N.S.

Nevertheless, RWC in mandarins and grapefruits was found at par with respective cultivars Pearl Tangelo, Kinnow, Duncan and Ruby Red. In general, the RWC was not significantly variable and was within the optimum range in various cultivars. However, for the cv. Jaffa, Duncan and Ruby Red during 2014 and mandarin hybrid Pearl Tangelo in both the years the differences in RWC were significant. The RWC of leaves during the months of June and July was low across all the species and their cultivars and hybrids investigated in the study.

DISCUSSION

Photosynthesis, transpiration and stomatal conductance rate

Among all species and cultivars maximum photosynthetic rate was recorded in Kinnow mandarin (6.74µmol/m^2/sec and 6.10µmol/m^2/sec) and minimum (3.52µmol/m^2/sec and 3.37µmol/m^2/sec) in Pearl Tangelo mandarin in both years. Lower rate of photosynthesis under water stress may be a result of lower diffusion of CO_2 across mesophyll cells and stomata causes down regulation of sweet orange tree photosynthesis under heat stress conditions (Flexas and Medrano, 2002 and Martin-Gorriz*et al.*, 2011). Mediavilla*et al.* (2001) strengthened our findings that leaf photosynthetic rate depends on photosynthetic components contents, such as RuBisco, cytochrome, H+-ATPase and reaction centers, also on leaf thickness and area per leaf mass. The photosynthetic rate of sweet orange and grapefruit was almost at equity to each other at fruit set (Table 1). It indicates that Kinnow was most photo-synthetically efficient cultivar in fixing more CO_2 among all cultivars and species of citrus under study.

The rate of transpiration reveals the extent of gaseous exchange in plants (Table 1). Maximum rate of transpiration was recorded in sweet orange cv. Pineapple (2.17µmol/m^2/sec and 2.14µmol/m^2/sec) with minimum transpiration in grapefruit cv. Duncan (1.80µmol/m^2/sec and 1.76µmol/m^2/sec). Findings of our study were in harmony with (Martin-Gorriz*et al.*, 2011; Machado *et al.*, 2005 and Machado *et al.*, 2002) that, under natural conditions, transpiration varied as a function of temperature and water vapour pressure deficit (VPD).

The stomatalconductance was highest in sweet orange cv. Jaffa (49.60 m mol/m^2/sec and 54.20 m mol/m^2/sec) and minimum in grapefruit cv. Ruby Red (41.30 m mol/m^2/sec and 44.40 m mol/m^2/sec) during 2014 and 2015 (Table 1). Findings of our study were in agreement with (Martin-Gorriz*et al.*, 2011; Machado *et al.*, 2005 and Machado *et al.*, 2002) that, stomata conductance is a function of temperature and water vapour pressure deficit (VPD). Apparently no marked differences in the stomata conductance were found among all the species of citrus.Citrus leaf stomata conductance (*g*s) is particularly sensitive to changes in leaf to air vapour pressure difference; *g*s decreases as leaf temperature leaf to air vapour pressure differenceincrease (Syvertsen and Salyani, 1991).

Leaf water potential and leaf osmotic potential

Pertaining data in Table 2 showed an observable difference in leaf water potential of various citrus species under the study. Significantly, higher leaf water potential was recorded in Sweet orange cv. Pineapple (1.38 and 1.44 -MPa) and lowest was in grapefruit cv. Ruby Red (1.65 and 1.60 -MPa) in both years within cultivars. During summers stressed new leaves reaches zero turgor with higher leaf water potentials. At higher temperature and low relative humidity causes reduction in leaf water potential due to which there is reduced carbohydrate synthesis and supply to reproductive sinks leads to reduced fruit size and yield. Ribeiro*et al*., 2008; Moringa and Sykes, 2001 and Mediavilla*et al.*, 2001 also in support of our findings.

Results illustrated difference in leaf osmotic potentials of various citrus species and cultivars in Table 2. A significantly higher leaf osmotic potential was reported in Ruby Red cv. of grapefruit i.e. (1.51and 1.85 -MPa). It revealed grapefruits leafs had a tendency to adjust them osmotically under stressed environment. But on the other hand in sweet orange cultivar Jaffa had least osmotic potential among all i.e. (1.95 and 1.81-MPa). Osmotic adjustment in response to water stress is considered an important physiological mechanism enabling plants to tolerate water deficits (Begg and Turner, 1970), can increase its resistance to dehydration through reduction in cellular osmotic potential by a net accumulation of cellular solutes (Hsiao *et al.*, 1976 and Guinchard*et al.*, 1996).

Cell membrane injury and Cell membrane stability index

Cell membrane injury (CMI)indicated that mandarin hybrid Kinnow was most tolerant to stress with minimum CMI i.e. (25.54 and 33.15%) in both years whereas, grapefruit cv. Duncan was found most sensitive in stress tolerance throughout study with maximum CMI values (44.70 and 44.81%) (Table 2).Cell membrane stability index (CMSI) depicted a marked difference in stress tolerating abilities of spring flush leaves in various cultivars of citrus under study. Thus, Kinnow mandarin was found most tolerant among all species with maximum (74.46 and 66.85%) CMSI and Duncan grapefruit was least tolerant with minimum (55.30 and 55.18%) stability in stress hours. Our findings were supported by several workers (Ismail and Hall, 1991; Srinivasan *et al.*, 1996 and Carfurd*et al.*, 2003).

Relative water content

Leaf relative water content (RWC) is a measure of plant water status data on which is presented in Tables 3a and 3b. As showed a significant decrease moving towards stress period of year (March to July), then slight increase in relative water content was observed in all species towards end of year. Highest mean RWC content within species was recorded in cv. Pineapple (84.48%; 85.04% 2014 and 2015) than Jaffa (84.48%; 85.04% during 2014 and 2015). But RWC in mandarins and grapefruits were found at par with respective cultivars content i.e. (Pearl Tangelo 83.51%, 84.96%, Kinnow 83.44%, 84.67%, Duncan 83.40%, 85.33%, Ruby Red 83.16%, 85.21%).

Statistically RWC was found non-significant, that RWC in various cultivars was within optimum range. Our results were in harmony with Panigrahi*et al.* (2014) and Taiz and Zieger (2002) that leaf RWC affects photosynthesis, soluble protein content of leaf so as RuBP carboxylase activity but remains uninfluenced of temperature might be due to osmotic adjustment (Barkataky, 2009).

REFRENCES

Barkataky, S. (2009).Role of temperature in water uptake of cold acclimated 'Hamlin' sweet orange. M.Sc. Thesis. University of Florida.68 p.

Begg, J.E. and Turner, N.C. (1970).Water potential gradients in field tobacco. *Plant Physiology*, **46**: 343-346.

Blum, A. and Ebercon, A. (1981).Cell membrane stability as a measure of drought and heat tolerance in wheat.*Crop Science*,**21**:43-47.

Brass, H.D. and Weathery, P.E. (1962). A re-examination of the relative turgidity technique of water stress studies. *Plant and Soil*, **39**: 206-207.

Carfurd, P.Q., Prasad, P.V.V., Kakani V.G., Wheeler, T.R. and Nigam, S.N. (2003).Heat tolerance in groundnut.*Field Crop Research,* **80**: 63-77.

Flexas, J. and Medrano, H. (2002). Drought-inhibition of photosynthesis in C_3 plants: Stomatal and non-stomatal limitations revisited. *Annals of Botany,* **89**: 183-189.

Guinchard, M.P., Robin, C., Grew, P. and Guckert, A. (1996). Cold acclimation in white clover subjected to chilling and frost: Changes in water and carbohydrate status. *European Journal of Agronomy,* **6**: 225-233.

Hsiao, T.C., Acevedo, E., Fereres, E. and Henderson, D.W. (1976). Stress metabolism. Water stress, growth, and osmotic adjustment.*Philosophical Transactions of the Royal Society*: *Biological Sciences,***273**: 479-500.

Iglesias, J. Domingo, Manuel Cercos, Jose M. Colmenero-Flores, Miguel A. Naranjo, Gabino Rios, Esther Carrera, Omar Ruiz-Rivero, Ignacio Lliso, Raphael Morillon, Francisco R. Tadeo and Manuel, Talon., (2007). Physiology of citrus fruiting.*Brazilian Journal of Plant Physiology*, **19**(4): 333-362.

Ismail, A.M. and Hall, A.E. (1999).Reproductive stage heat tolerance, leaf membrane thermostability and plant morphology in cowpea.*Crop Sciences,***39**: 1762-1768.

Jifon, J.L. and Syvertsen, J.P. (2003). Moderate shade can increase net gas exchange and reduce photo inhibition in citrus leaves. *Tree Physiology,***23**: 119-127.

Kriedemann, P.E. and Barras, H.D. (1981).Citrus orchards. In: *Water Deficits and Plant Growth.***6**, Kozlowski, T. T., (Ed) Acedimic Press. New York, 92p.

Machado, E.C., Medina, C.L., Gomes, M.M.A. and Habermann, G. (2002). Seasonal variation of photosynthesis, stomatal conductance and water potential orange leaf 'Valencia'.*Journal of Agricultural Science,* **59**: 53-58.

Machado, E.C., Schmidt, P.T., Medina, C.L. and Ribeiro, R.V. (2005).Photosynthesis responses of three species of citrus to environmental factors.*PesquisaAgropecuariaBrasileria,***40**: 1161-1170.

Martin-Gorriz, B., Egea, G., Nortes, P.A., Baille, A., Gonzalez-Real, M.M. and Ruiz-Salleres, I. (2011). Effects of high temperature and vapour pressure deficit on net ecosystem exchange and energy balance of an irrigated orange orchard in a semi-arid climate (southern spain). *Proceedings of the XXVIIIth IHC –IS on Water Use in a Changing World* (Eds.): Fernandez, J.E. and Ferreira, M.I. *ActaHorticulturae.*149-156.

Mediavilla, S., Escudero, A. and Heilmeier, H. (2001). Internal leaf anatomy and photosynthetic resource use efficiency: interspecific and intraspecific comparisons. *Tree Physiology,***21**: 251-259.

Mendel, K. (1969). The influence of temperature and light on the vegetative development of citrus trees.*Proceedings of the 1st International Citriculture Symposium, Citrus Congress*, Riverside, California, **1**: 259-265.

Morinaga, K. and Sykes, R.S. (2001).Effect of salt and water stress on fruit quality, physiological responses, macro-micro element contents in leaves of Satsuma mandarin trees under greenhouse conditions.*Japan Agricultural Research Quarterly,* **35**(1): 53-58.

Panigrahi, P., Raman, K.V. and Sharma, R.K. (2014).Sensing tree for yield forecasting under differential irrigation.*International Journal of Research in Agriculture and Forestry,***1**(2): 23-30.

Poerwanto, R. and Inoue, H. (1990).Effects of air and soil temperature on flower development and morphology of Satsuma mandarin.*Journal of Horticultural Sciences,* **65**: 739-745.

Ribeiro, R.V., Machado, E.C., Espinoza-Nunez, E., Ramos, R.A., Machado, D.F.S.P. (2012). Moderate warm temperature improves shoot growth, affects carbohydrate status and stimulates photosynthesis of sweet orange plants. *Brazilian Journal of Plant Physiology,* **24**(1): 37-46.

Ribeiro, R.V., Rolim, G.de.S.,Azevedo, F.A.de. and Machado, E.C. (2008). 'Valencia' sweet orange tree flowering evaluation under field conditions.*Agricultural Sciences,***65**(4): 389-396.

Saxena, M. and Gandhi, C.P. (2015).*Indian Horticulture Datebase-2014.*National Horticulture Board, Ministry of Agriculture.Government of India, Gurgaon.www.nhb.gov.in

Spiegel-Roy, Pinhas and Goldschmidt, E. Eliezer. (1996). *Biology of Citrus,* Cambridge University Press Inc., New York, NY, USA.

Srinivasan, A., Takeda, H., Senboku, T. (1996).Heat tolerance in food legumes as evaluated by cell membrane thermostability and chlorophyll fluorescence techniques. *Euphytica,* **88**(1): 35-45.

Syvertsen, J.P. and Salani, M. (1991). Petroleum spray oil effects on net gas exchange of grapefruit leaves at various vapour pressures, *HortScience*, **26**: pp. 168.

Taiz, L., and Zeiger, E. (2002).*Plant Physiology* (3rd ed.), Sinauer Associates, Inc., Sunderland, M.A. 690 p.