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Assessment of water relation traits during different phenological stages in mango (*Mangifera indica* L.)

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ABSTRACT

In mango, water stress plays an important role in flowering & fruiting regulation as it provides the floral induction signal. Pressure volume curve (P-V curve) was used to derive basic water relation parameters, *viz.,* osmotic potential, symplastic and apoplastic water content, solute potential at full turgor, turgor loss point, water content at turgor loss point and elasticity modulus in plant system. In the present paper Amrapali and Langra mango cultivars having regular and irregular bearing habit, were studied in order to understand the leaf responses to different water status. The effect of paclobutrazol (PP_{333}), a growth retardant having anti-gibberellin activity and induce the flowering even in the 'Off' year on these parameters was also studied. During flower bud differentiation (FBD), Amrapali had more osmotic potential (-3.39 MPa) than Langra (-5.38 MPa) without any significant shift with paclobutrazol treatment. However, osmotic potential increased markedly in trees treated with paclobutrazol (2 g a.i./ tree) at flower bud burst and panicle emergence stages as compared to control. Langra exhibited lower turgor loss point (-5.56 MPa) than Amrapali (-5.41 MPa) at FBD, which indicate early turgor loss in leaves of Langra than Amrapali during the critical period of flowering. Amrapali showed lower turgor loss point (TLP) in subsequent stages of flower development, which may signify that with lower TLP it may be able to maintain osmoregulation at lower leaf water potentials. Sap flow also varied significantly in these cultivars as Amrapali had higher range of sap flow (6.76-18.99 kg/h) than Langra (6.91-13.11 kg/h) in different flower developmental stages. The results of this study showed that adjustment for water stress may be greater in Amrapali than Langra sharing same habitat but having different bearing pattern. Better osmoregulation may be helpful for Amrapali to outgrow better than Langra under subtropical conditions.

Key words: *Mangifera indica* L., relative water content, osmotic adjustment, water potential.

INTRODUCTION

Water stress is one of several factors which affect mango production (Balley *et al*., 2). Information on water relations and irregular bearing pattern influenced by water stress in mango is limited. Pressure-volume analysis is used to determine various water relation parameters of the plants (Lenz *et al*., 6) such as the osmotic and pressure potentials of the symplast and apoplast, the bulk modulus of elasticity (E) and Turgor loss point (TLP). Application of this technique requires starting the plant tissue at near zero water potential (Ngugi *et al*., 9). The leaves collected from the tree are generaly at water potential considerably less than zero, and therefore it must be rehydrated for further study. Pressure volume curve (P-V curve) is a plot of inverse water potential, which by definition declines linearly with RWC below the Turgor loss point (TLP) (Tyree and Hammel, 14). From P-V curve, symplastic water fraction (R's) is estimated by extrapolating the straight-line section with large negative water potential and TLP is estimated as the point where the line becomes non-linear (Sobrado, 11). These traits may differ between varieties and individual plants can adjust them over time.

Sap flow is generally used to study the movement of water through conductive xylem of tree. Its pattern may not be homogenous across the tree at different phenological stages therefore investigation on its profile during different flower developmental phenology in mango is important to study. Among plant growth retardant, paclobutrazol is considered as one of the important plant growth retardant which restricts vegetative growth, induces flowering and fruiting in many fruit species including mango (Abdel *et al*., 1; Singh and Singh, 10). Paclobutrazol treated plants may maintain high leaf turgor at high traspirational demand and better able to withstand stress conditions (Chaves *et al*., 4). Keeping this in view, the inter-relationship of paclobutrazol with estimated water related parameters in mango was studied.

MATERIALS AND METHODS

The present investigations were carried out with full bearing trees of 'Langra' (biennial) and 'Amrapali' (regular) mango cultivars during year 2010-11 and

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2011-12 at ICAR-CISH, Rehmankhera, Lucknow located at 26.54°N Latitude, 80.45°E Longitude and 127 m. above mean sea level. The soil is mixed hyperthermic family of typical Ustochrepts with sandy loam texture. The range of average maximum and minimum temperatures was 18.5-38.6 and 5.0-25.3, respectively during experimental period. The rainfall recorded ranged between 3.7-17.5 mm during the same period and relative humidity was in the range of 71.7-88.9% with mean daily pan evaporation ranged from 1.3-11 mm. A single soil drenching of paclobutrazol @ 2, 4, 6 and 8 g a.i. per tree in the root zone at 15 cm depth was applied during the month of September. Both under paclobutrazol treated and control, four trees were taken. Untreated trees were kept as control. About 50 potential healthy shoots were tagged from each direction and recently fully matured leaves adjacent to apical meristem having same age and orientation as standardized earlier (Yadava and Singh, 15) were collected. Sampling of leaves for assessment of different water relationship parameters was done at different stages of flowering, *i.e.* before flower bud differentiation, flower bud differentiation, bud burst and panicle elongation. The experiment was performed in a complete randomized design with five replications.

The plant water status was determined by simultaneous measurements of water potential (Ψw) and leaf water content (LWC). Each excised leaf was immediately put inside zip pouch for Ψw measurement. All predawn and midday Ψw measurements were made with water potential measurement system (WP4 & WP4-T Dewpoint Meters, Decagon Devices, USA).Values of LWC were determined as: LWC = 100 (FM-DM)/ FM. Where FM is leaf fresh mass and DM is leaf dry mass. Dry mass was determined after drying the leaf samples at 80°C for 24 h. Values of LWC were expressed as relative water content (RWC) by determining FM, DM and saturated mass (SM) as RWC = (FM−DM)/ (SM−DM).

For determination of water potential petioles was cut underwater and leaves were hydrated in potable tap water (room temperature and kept in the dark for 24 h); after equilibration (2.5 h) of leaf sample a disc (approx. 100 mg) was taken from mid portion of leaf and Ψw was measured. Leaf discs were left to dry on the bench between measurements and were weighed after every 10 min interval (till it reaches at weighed difference of 0.001 g) immediately before and after water potential was measured with a C-52 thermocouple psychrometer. Water potential was measured using standard procedures (Turner, 13). Standard solution of known water potential (Ψw) was always run with samples and values corrected to a temperature of 25°C. After equilibration the water potential (Ψw) was measured after 10 min. interval as the leaf disc loses 2-3 mg water. This was repeated until 10-12 measurements had been made on each sample, and the plants had reached a RWC of approx.16% and 5% and a Ψw of approx. -7.0 and -5.0 MPa for Amrapali and Langra, respectively.

For the P-V curves, five replicate of P-V curves were measured for both the varieties. Water relation parameters of these two varieties were calculated from pressure-volume isotherms. P-V curve was drawn on the basis of RWC and reciprocal of Ψw on × and y axis, respectively as described earlier. Turgor-loss points were obtained by subjecting previously rehydrated leaves to a series of paired measurements of WP and relative water content (RWC) as they were allowed to air-dry. TLP was determined from the start of the straight line, from plots of inverse balance pressure vs. shoot fresh mass. Calculation of the other water relation traits from p-v curve was followed by the standard procedure. Sap flow at different stages of flowering was measured by Sap Flow System EMS in both the varieties with five replications in each direction of the tree. The measuring principle is based on the tissue heat balance method (THB) with internal heating and sensing (Cermak *et al.*, 3). The sap flow value of shoots was calculated as per the method described by Tatarinov *et al.* (12). All measurements were expressed as mean of five measurements (±SE) from each tree per treatment. Significant differences were detected at $p = 0.05$, according to the Student's *t* test.

RESULTS AND DISCUSSION

The Table 1 (A, B, C, D) presents important parameters, *viz.* osmotic potential (OP), symplastic (R's) and apoplastic water content (R'a), solute potential at full turgor (SPAFT), turgor loss point (TLP), water content at turgor loss point (WCTLP) and elasticity modulus (E) at different phenophases which were derived from P-V curve (Fig. 1A & 1B) at FBD stage for two cultivars (P-V curve for rest of the stages were not shown). Parameters in the table clearly revealed that during FBD Amrapali had more OP (-3.39 MPa) than Langra (-5.38 MPa) without any significant change with paclobutrazol. However OP increased markedly in trees treated with paclobutrazol (2 g a.i./ tree] at flower bud burst and panicle emergence stages as compared to control. Osmotic potential increases in paclobutrazol treated trees (Amrapali = -3.23 MPa; Langra = -5.18 MPa) as compared to control one (Amrapali = -3.39 MPa; Langra = -5.38 MPa). This finding showed that paclobutrazol had osmoregulatory capacity in order to maintain water status of tree during active and stressed stage of flower bud development. Symplastic

Table 1A. Changes in water relation parameters of Amrapali (A) and Langra (L) at flower bud differentiation with paclobutrazol treatments.

Parameter	Control		2 g a.i.		4 g a.i.		6 g a.i.		8 g a.i.	
	A	L	A	L	A	L	A	L	A	L
OP	-3.39 ± 0.11	-5.38 ± 0.23	-3.23 ± 0.12	-5.18 ± 0.41	-3.23 ± 0.13	-5.18 ± 0.63	-3.39 ± 0.11	-5.05 ± 0.78	-3.23 ± 0.10	-5.13 ± 0.56
R's %	76.00 ± 5.66	60.00 ± 6.52	89.00 ± 8.71	73.00 ± 7.11	92.00 ± 6.23	75.00 ± 7.23	87.00 ± 8.41	75.00 ± 7.14	83.00 ± 6.33	72.50 ± 5.64
R'a %	24.00 ± 1.23	40.00 ± 3.63	11.00 ± 1.21	27.00 ± 3.22	8.00 ± 0.98	25.00 ± 2.33	13.00 ± 1.21	25.00 ± 2.45	17.00 ± 1.86	27.50 ± 3.44
SPAFT	-3.39 ± 0.11	-5.38 ± 0.23	-3.23 ± 0.12	-5.18 ± 0.41	-3.23 ± 0.13	-5.18 ± 0.63	-3.39 ± 0.11	-5.05 ± 0.78	-3.23 ± 0.10	-5.13 ± 0.56
TLP	-5.41 ± 0.47	-5.56 ± 0.89	-5.26 ± 0.87	-5.52 ± 0.95	-5.56 ± 0.87	-5.56 ± 0.75	-5.41 ± 0.66	-5.78 ± 0.89	-5.56 ± 0.91	-5.49 ± 0.93
WCTLP	33.00 ± 5.66	48.00 ± 7.11	26.00 ± 2.33	31.00 ± 6.33	20.00 ± 1.22	34.00 ± 2.63	11.90 ± 1.24	25.00 ± 2.21	14.00 ± 1.11	45.00 ± 7.11
E	2.21 ± 0.91	5.12 ± 0.41	2.75 ± 0.23	0.66 ± 0.09	3.27 ± 0.78	2.02 ± 0.23	2.42 ± 0.41	0.87 ± 0.08	2.80 ± 0.25	0.55 ± 0.04

E = Elasticity modulus, OP = Osmotic potential, R's = Symplastic water content, R'a = Apoplastic water content, SPAFT = Solute potential at full turgor, TLP = Turgor loss point, WCTLP = Water content at turgor loss point; Data are expressed as a pooled mean ± standard deviation

Table 1B. Change in water relation parameters of Amrapali (A) and Langra (L) at bud burst stage with paclobutrazol treatments.

Parameter	Control		2 g a.i.		4 g a.i.		6 g a.i.		8 g a.i.	
	A	L	A	L	A	L	A	L	A	L
OP	-6.49 ± 0.91	-6.62 ± 0.33	-4.55 ± 0.23	-6.45 ± 0.45	-6.37 ± 0.56	-6.29 ± 0.44	-6.41 ± 0.65	-6.25 ± 0.41	-6.67 ± 0.77	-0.61 ± 0.44
R's %	78.00 ± 7.41	82.80 ± 9.71	81.00 ± 8.99	78.80 ± 9.88	81.00 ± 8.79	76.70 ± 8.45	76.00 ± 9.77	73.40 ± 8.75	66.00 ± 6.78	80.50 ± 8.11
R'a %	22.00 ± 4.56	17.20 ± 2.33	19.00 ± 8.74	21.20 ± 2.33	19.00 ± 4.11	23.30 ± 3.41	24.00 ± 2.63	26.60 ± 3.22	34.00 ± 2.52	19.50 ± 3.11
SPAFT	-6.49 ± 0.91	-6.62 ± 0.33	-4.55 ± 0.23	-6.45 ± 0.45	-6.37 ± 0.56	-6.29 ± 0.44	-6.41 ± 0.65	-6.25 ± 0.41	-6.67 ± 0.77	-0.61 ± 0.44
TLP	-6.99 ± 0.74	-6.62 ± 0.66	-7.09 ± 0.74	-6.94 ± 0.85	-7.14 ± 0.99	-6.15 ± 0.78	-7.04 ± 0.91	-6.94 ± 0.66	-6.67 ± 0.71	-6.62 ± 0.23
WCTLP	36.00 ± 2.33	27.00 ± 1.22	29.00 ± 2.33	20.00 ± 3.66	26.00 ± 4.41	33.00 ± 3.66	25.00 ± 2.63	26.00 ± 1.42	31.00 ± 1.56	22.00 ± 1.11
E	0.89 ± 0.11	0.55 ± 0.09	1.15 ± 0.23	0.97 ± 0.14	0.99 ± 0.11	0.25 ± 0.09	0.96 ± 0.08	1.00 ± 0.04	0.80 ± 0.07	0.58 ± 0.04

E = Elasticity modulus, OP = Osmotic potential, R's = Symplastic water content, R'a = Apoplastic water content, SPAFT = Solute potential at full turgor, TLP = Turgor loss point, WCTLP = Water content at turgor loss point; Data are expressed as a pooled mean ± standard deviation

Table 1C. Changes in water relation parameters of Amrapali (A) and Langra (L) mango at panicle emergence with application of paclobutrazol.

Parameter	Control		2 g a.i.		4 g a.i.		6 g a.i.		8 g a.i.	
	A	L	A	L	A	L	A	L	A	L
OP	-6.49 ± 0.52	-6.29 ± 0.66	-4.55 ± 0.71	-6.45 ± 0.56	-6.33 ± 0.87	-6.41 ± 0.11	-6.33 ± 0.56	-6.29 ± 0.47	-6.41 ± 0.44	-6.25 ± 0.56
R's %	76.00 ± 4.11	80.00 ± 5.56	81.00 ± 4.89	78.10 ± 7.11	65.00 ± 6.63	76.60 ± 4.56	79.00 ± 5.89	77.40 ± 6.61	77.00 ± 5.56	83.80 ± 6.63
R'a %	24.00 ± 2.33	20.00 ± 4.56	19.00 ± 1.22	21.90 ± 2.63	35.00 ± 4.56	23.40 ± 2.66	21.00 ± 3.21	22.60 ± 2.54	23.00 ± 3.14	16.20 ± 2.56
SPAFT	-6.49 ± 0.52	-6.29 ± 0.66	-4.55 ± 0.71	-6.45 ± 0.56	-6.33 ± 0.87	-6.41 ± 0.11	-6.33 ± 0.56	-6.29 ± 0.47	-6.41 ± 0.44	-6.25 ± 0.56
TLP	-6.94 ± 0.87	-6.62 ± 0.56	-7.09 ± 0.78	-6.99 ± 0.98	-7.14 ± 0.45	-6.62 ± 0.63	-7.04 ± 0.84	-7.04 ± 0.85	-6.90 ± 0.66	-6.62 ± 0.87
WCTLP	44.00 ± 4.11	30.00 ± 8.74	25.90 ± 2.33	31.00 ± 6.33	17.00 ± 1.22	25.00 ± 2.54	21.00 ± 3.85	10.00 ± 1.24	32.00 ± 2.88	25.00 ± 3.74
E	0.81 ± 0.09	0.55 ± 0.01	1.15 ± 0.44	1.00 ± 0.23	0.99 ± 0.12	0.57 ± 0.07	0.87 ± 0.08	1.00 ± 0.25	0.79 ± 0.33	0.60 ± 0.41

E = Elasticity modulus, OP = Osmotic potential, R's = Symplastic water content, R'a = Apoplastic water content, SPAFT = Solute potential at full turgor, TLP = Turgor loss point, WCTLP = Water content at turgor loss point; Data are expressed as a pooled mean ± standard deviation

Table 1D. Change in water relation parameters of Amrapali (A) and Langra (L) mango at panicle elongation with paclobutrazol application.

Parameter	Control		2 g a.i.		4 g a.i.		6 g a.i.		8 g a.i.	
	A	L	A	L	A	L	A	L	A	L
OP	-6.21 ± 0.52	-6.67 ± 0.74	-6.37 ± 0.66	-6.67 ± 0.53	-6.90 ± 0.56	-6.67 ± 0.56	-6.13 ± 0.74	-6.41 ± 0.56	-6.29 ± 0.89	-6.45 ± 0.74
R's%	80.00 ± 7.41	86.20 ± 9.66	68.00 ± 8.74	75.90 ± 7.56	90.00 ± 7.45	90.00 ± 8.11	77.00 ± 7.41	79.30 ± 8.66	69.00 ± 7.56	79.30 ± 7.41
R'a%	20.00 ± 2.33	13.80 ± 1.22	32.00 ± 2.56	24.10 ± 3.41	10.00 ± 2.56	10.00 ± 2.11	23.00 ± 2.32	20.70 ± 2.41	31.00 ± 2.66	20.70 ± 2.45
SPAFT	-6.21 ± 0.52	-6.67 ± 0.74	-6.37 ± 0.66	-6.67 ± 0.53	-6.90 ± 0.56	-6.67 ± 0.56	-6.13 ± 0.74	-6.41 ± 0.56	-6.29 ± 0.89	-6.45 ± 0.74
TLP	-7.35 ± 1.22	-7.14 ± 2.12	-7.41 ± 2.36	-7.09 ± 1.45	-7.81 ± 3.11	-7.41 ± 1.22	-6.80 ± 2.41	-7.09 ± 1.22	-7.04 ± 2.36	-6.99 ± 1.32
WCTLP	35.00 ± 3.66	26.00 ± 4.74	45.00 ± 5.11	27.00 ± 1.22	11.00 ± 0.89	20.00 ± 0.74	45.00 ± 5.22	34.00 ± 1.23	51.00 ± 6.89	37.00 ± 2.63
E	1.89 ± 0.08	0.97 ± 0.11	1.75 ± 0.23	0.98 ± 0.07	1.61 ± 0.11	1.38 ± 0.05	1.61 ± 0.08	0.99 ± 0.11	0.91 ± 0.04	0.86 ± 0.11

E = Elasticity modulus, OP = Osmotic potential, R's = Symplastic water content, R'a = Apoplastic water content, SPAFT = Solute potential at full turgor, TLP = Turgor loss point, WCTLP = Water content at turgor loss point; Data are expressed as a pooled mean ± standard deviation

content (R's) also found more in Amrapali (76.00%) than Langra (60.00%) at FBD as a result apoplastic content (R'a) appeared reverse pattern among two varieties as indicated by lower value in Amrapali (24.00%) than Langra (40.00%). Paclobutrazol showed positive response and increased symplastic content after FBD in both the varieties. Its value was found higher in Langra (73.40-82.80%) than Amrapali (66.00-78.00%) after FBD, which ultimately increases R'a in Amrapali (32.44-44.00%) than Langra (17.20-26.60%). On the other hand at FBD Langra exhibited lower TLP (-5.56 MPa) than Amrapali (-5.41 MPa), which indicate early turgor loss in leaves of Langra during the critical period of flowering process. Turgor loss point increases (Amrapali = -5.26; Langra = -5.52) with treatment as compared to control (Amrapali = -5.41; Langra = -5.56) condition. Bulk modulus of elasticity was found 2.21 and 5.21 MPa for Amrapali and Langra, respectively at flower bud differentiation (FBD), which showed that former had more elasticity than later at FBD. It was found that during flowering period Amrapali reached to -9.0 MPa and recovered more completely after panicle elongation (-3.1 MPa) while on other hand Langra reached at -7.0 MPa and could not recover completely. Elasticity decreased during the time of flower bud differentiation (Amrapali = 1.15; Langra = 0.97) and increased at onset of panicle emergence (Amrapali = 0.79; Langra = 0.60) in both the varieties than control (Amrapali = 0.89; Langra = 0.55) indicating maintenance of turgor in treated trees as a function of the dynamic process of cell wall adjustment, as reflected by marked reductions in both the saturated and turgor-loss volumes and by maintenance of elastic coefficients of the tissues.

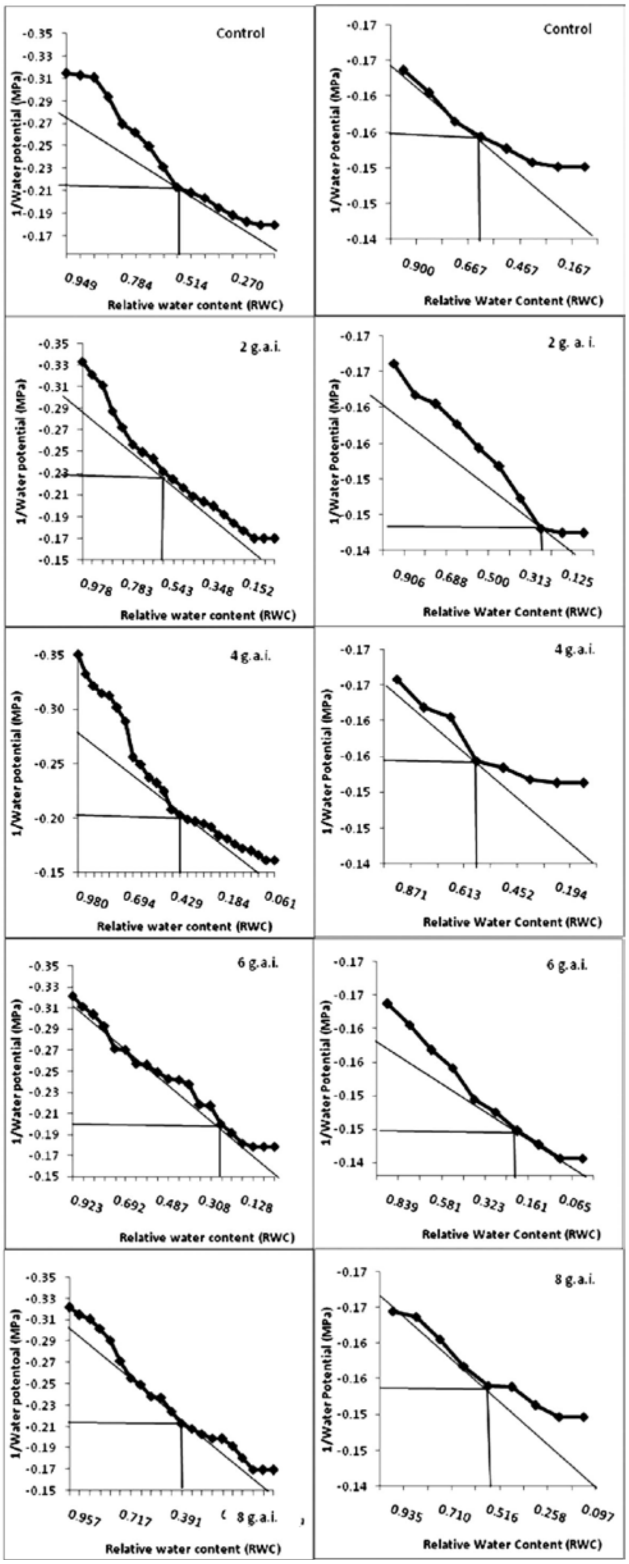
Sap flow measurements were also made on two varieties (Table 2), which showed that Amrapali (6.76-18.99 kg/h) had higher sap flow than Langra (6.91-13.11 kg/h) in different flower developmental stages being maximum (Amrapali = 12.88 ± 1.89, Langra = 6.91 ± 0.99 kg/h) at panicle elongation and minimum (Amrapali = 6.76 ± 0.88, Langra = 6.91 ±

Table 2. Sap flow in mango Amrapali (A) and Langra (L) mango genotypes.

Stage	Sap flow (kg/ h)	
	Amrapali	Langra
Flower bud differentiation (FBD)	10.12 ± 1.21	9.11 ± 1.99
Bud burst (BB)	6.76 ± 0.88	6.91 ± 0.78
Panicle emergence (PEe)	12.67 ± 2.11	8.80 ± 0.99
Panicle elongation (PE)	12.88±1.89	8.32±0.96

Data are expressed as a pooled mean ± standard deviation

0.89 kg/h) at bud burst stage of flower development (Fig. 2). The result confirms that the value of P-V curve obtained by thermocouple psychrometer as an alternative or supplement to other methods for evaluating water relations parameters of Langra and Amrapali, including some quantities that cannot be estimated satisfactorily in any other way. The plot onto a graph of 1/ψ against water content is a curved line, which is concave to the y-axis. RWC in a measured P-V curve is the sum of this (curvilinear) apoplast component and the (theoretically linear) symplast component. P-V curve clearly indicates that total water content of saturated Amrapali tends to be higher than Langra. Amrapali contains more apoplastic water content. A possible explanation for this may be that Amrapali tends to have higher contents of cell wall uronic acids, which can readily bind water. The higher water-holding capacity of Amrapali will allow it to continue metabolism for longer than Langra. While this could be viewed as a form of 'desiccation avoidance', Amrapali also recovers faster than Langra during rest period suggesting that they have higher inherent tolerance. This may help them to persist in stress exposed duration. In contrast, Langra lacks such strong avoidance and tolerance mechanisms. Amrapali showed lower TLP in subsequent stages of flower development, which may signify that with lower TLP Amrapali should be able to maintain osmoregulation at lower leaf water potentials. Varieties with lower TLP should be able to continue growth at lower leaf water potential (Ingram and Bartels, 5). Paclobutrazol showed positive response and increased Symplastic content after FBD in both the varieties. R's value was found higher



(A) **(B)**

Fig. 1. (A) P-V curve for Amrapali and (B) Langra mango genotypes. Each point represents mean ± s.d. of five replicates.

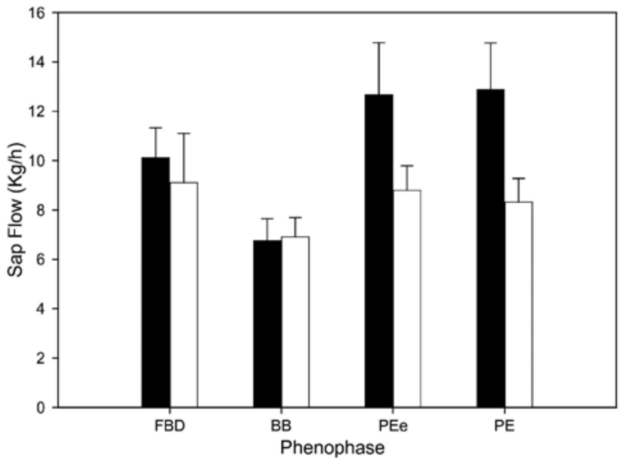


Fig. 2. Sap flow of Amrapali (■) and Langra (□) at different phenophases. FBD = flower bud differentiation, BB = bud burst, Pee = panicle emergence and PE = panicle elongation.

in Langra after FBD this increases R'a in Amrapali, which is an indicator of highly adjusting nature of former variety against water deficit during flowering than later one as high R'a value supports stress tolerant capacity. Turgor regulation at reduced water contents was closely associated with changes in the elastic quality of the cell walls. An understanding of sap dynamics in mango cultivars is very important in devising a strategy for irrigation in mango. The greater sap flow at panicle elongation than flower bud differentiation might be due to the high water content or turgor pressure, which declined with increased stress as with the increase in stress loss of water through transpiration decreased the sap quantity. Langra had more rigid cell walls than Amrapali and as a result during flowering period Langra lost more water before turgor started dropping (at higher RWC) than Amrapali and at less negative osmotic potential during stress as a result PSII started declining earlier. Increased elasticity (decreasing E, *i.e.* decreasing the slope between full turgor and TLP) was associated with less negative solute potential in Amrapali than Langra.

Paclobutrazol-treated trees showed marked increases in stress resistance, and pressure-volume analysis confirmed that water stress was ameliorated during stress period. Turgor was maintained in the paclobutrazol-treated trees despite water contents near or below the turgor-loss volumes of well-watered controls. The maintenance of turgor in these trees was in large part a function of the dynamic process of cell wall adjustment, as reflected by marked reductions in both the saturated and turgor-loss volumes and by large increases in the elastic coefficients of the tissues. In this study, the plants treated with PBZ appear to have been more resistant to stress than those without PBZ treatment. Similar results have been reported for bean, jack pine, white spruce and black spruce (Marshall *et al*., 7). The treatment-induced reductions in water contents enabled trees to maintain turgor with tissue volumes close to, or below, the turgor-loss volume of untreated trees. The role of paclobutrazol in lowering water consumption and reduced water loss in treated plants was already been recorded (Navarro *et al*., 8). Sap flow data showed decreasing pattern during successive stages of flower bud differentiation, which confirms internal stress during these stages. After panicle elongation both varieties started regaining their water status which was faster in Amrapali than Langra. The results of the present study clearly showed that desiccation tolerance is greater in Amrapali than Langra sharing same habitat. Desiccation tolerance can help Amrapali to outgrow the competition of Langra that normally grow in association with it.

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