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Relationship of plant water status and leaf gas exchange with fruit cracking of pomegranate

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ABSTRACT

Plant water status and leaf gas exchange as influenced by micronutrients, kaolin and water management were studied to establish a relationship with fruit cracking in pomegranate in arid regions. Observations were recorded on fruiting pomegranate trees that were maintained under different water status and leaf gas exchange through mulching of tree basins and foliar spray of borax (0.4%), zinc sulphate (0.5%), kaolin (4.0%) with respect to fruit cracking, LWP, RWC, stomatal conductance, transpiration, photosynthetic rate and difference between ambient and leaf temperature of fruiting branch. The results showed that per cent fruit cracking was associated with reduction in leaf water potential, stomatal conductance and leaf transpiration. Such a situation coupled with high relative water content and photosynthetic rate as observed under combined sprays of borax (0.4%) + $ZnSO_4$ (0.5%) and borax (0.4%) + $ZnSO_4$ (0.5%)+ kaolin (4%) reflects the possible relationship of fruit cracking with selected physiological parameters. Plant water status also influences leaf gas exchange parameters and subsequently growth which may indirectly affect cracking in pomegranate fruits.

Key words: *Punica granatum,* mulching, micronutrients, kaolin, water management.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is an important commercial fruit plant species of arid and semi arid region of the world. India occupies the first position in the world with respect to pomegranate area (1.3 lakh/ha) and production (8.21 lakh tonnes). Maharashtra, Karnataka, Gujarat, Andhra Pradesh, Tamil Nadu and Rajasthan are primarily pomegranate growing states of which the first three contribute about 85% of total production (Babu, 2). Owing to xerophytic characters, high yield potential, excellent quality and high economic return, pomegranate is becoming preferred cash crop among the farmers of arid districts of Rajasthan. Recent plantations of tissue culture seedlings under drip-fertigation system has revolutionized the pomegranate cultivation in arid and semi arid Rajasthan. The growth of pomegranate cultivation in Rajasthan can be easily visualized from the acreage expansion from 793 ha during 2010-11 to more than 6000 ha during 2016-17. Undoubtly the region has shown substantial growth in pomegranate but high incidence of fruit cracking becomes a serious problem in arid regions. Though fruit cracking occurs in practically all pomegranate growing areas but the magnitude in arid regions is as high as 62 per cent in some varieties (Prasad *et al.,* 5). The possible reason might be very high evapo-transpiration, low humidity, water imbalance and sharp temperature fluctuation in day and night during fruit growth and development (Abd and Rahman, 1). Besides high temperature, drought causes desiccation of the plants and consequently the fruit skin become hard and less elastic. Management of fruit cracking through several horticultural practices like spraying of growth promoters, micronutrients, antitranspirants and regular irrigation with drip and mulching have been recommended (Waskar, 13). Previous study at CAZRI established that cracking could be minimized by proper irrigation (by drip irrigation system), soil moisture conservation (by mulching) and balanced nutrients (by 0.4% borax and 0.5% zinc sulphate and 4% kaolin) (Singh *et al*, 11) but still there is need to understand the basic mechanism involved at the physiological plane in plant system by these treatments so as to propose more elaborative and effective measures on sustainable basis for management of cracking. The present study lays emphasis on identifying physiological parameters associated with less cracking of fruits in pomegranate cv. Jalore Seedless trees under arid conditions.

MATERIALS AND METHODS

The present investigations were carried out at ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan, India during 2014-15 under drip system of irrigation. The experimental site is situated at an elevation of 216 m from above mean sea level and lies between $26^0$18'N latitude and $73^0$04' E longitude. The weather conditions of the site is arid with very high temperature during the summer touching a

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maximum of 48^{0}C, short (December to mid- February) cool and dry winters (temperature varies from 4.1 to 14^{0}C), high evaporation (3.5 to 13.5mm day^{-1}) and generally low humidity (35 to 70 per cent). The region is characterized by a monsoon climate with the wet season extending from the end of June to September. About 95% of the average annual precipitation is received during this period. Total rainfall during experimental period was 363.6 mm.

The soil of the experimental site belonged to the typical Pal series and contained high percentage of fine and coarse sand. The pH of soil varied from 8.2 to 8.4 having average organic carbon (0.217%), total nitrogen (0.03%), available P_2O_5 (23.8 kg ha^{-1}) and available K_2O (359 kg ha^{-1}).

Twenty four plants of 18 years old pomegranate cv. Jalore Seedless of uniform size and vigor planted at 5 mx4 m apart were used as experimental materials and all plants were given uniform cultural practices. The level of irrigation through drip system i.e. @ 8 l/hour for three hours equals to 48 liters/plant was applied to all the plant based on previous study at this institute by Prasad *et al.,* (5). The experiment was laid out in completely randomized block design; tree basins (2m^2) were mulched (M1) with black polythene (150 µ) in one block while in another block no mulching (M2) was done. The treatments comprised of foliar sprays of 0.4% borax + 0.5% zinc sulphate ($ZnSO_4$) (T1), 0.4% borax + 0.5% zinc sulphate ($ZnSO_4$) + 4% kaolin (T2) applied at full bloom and 1 month after full bloom. Water spray (T3) and no spray (T4) served as control and master control, respectively. Each treatment was replicated thrice. Crop was retained for *Mrig Bahar* flowering in July-August.

Observations on fruit cracking were taken in triplicate during each picking from December onwards The total numbers of un-cracked and cracked fruits were counted and fruit cracking was calculated on per cent basis. Sampling in triplicate for estimation of physiological parameters viz. relative water content (RWC) of leaves, water potential of twigs/branches bearing fruits, leaf photosynthesis, transpiration rates and stomatal conductance were done during fruit growth and development in November and December of 2014. Leaf water potential was measured using pressure chamber (PMS Instrument Co., USA Model 1003), while RWC was measured following the method described by Slatyer and McIlroy (12) and calculated using the formula:

$$RWC = [(\text{Fresh weight} - \text{dry weight}) / (\text{turgid weight} - \text{dry weight})] \times 100$$

Photosynthesis, transpiration rates and stomatal conductance were measured by a portable photosynthesis system CIRAS-2 following standard procedure.

Though biological relevance of relationship status of physiological parameters with ultimate growth, fruit yield and characteristics (including cracking) exists but still to assess the extent of relationship in quantitative terms , the data of both the samplings (November and December) were statistically analyzed individually primarily because the fruiting and its harvest continues from early December to third week of January in the present investigation.

Correlations among different parameters were also estimated following 'stats' package of R programming environment (R Core Team, 7). Only significant correlations at P=0.05 (+/- 0.40) and/or P=0.10 are discussed further.

RESULTS AND DISCUSSION

Harvesting of matured fruits was done from first week of December and continued up to last week of January with almost more than 75 per cent of harvesting by end of December. Overall per cent fruit cracking after complete harvest was significantly less (27.15%) in mulched compared to non-mulched treatment (Table 1). Beneficial effects of mulching could be due to better soil moisture in these treatments as also reported in our earlier work wherein mulched plants had higher soil moisture than non mulched plants (Singh *et al.,* 11). Further, less fluctuation in soil moisture throughout the fruiting season as observed in basin of plants foliar sprayed with different chemicals (Singh *et al.*, 11) may also account for less cracking in these treatments as pomegranate fruit is very sensitive to variations in soil moisture (Abd and El-Rhman, 1).

Mulched plants, in November, invariably experienced less water deficit and high relative water content in their leaves compared to non-mulched plants. Further, these plants recorded high rate of photosynthesis coupled with slightly less stomatal conductance and transpiration rate. Though stomatal conductance and transpiration rate provides a good indication about root-to-shoot hydraulic conductance but they cannot account for all the variation observed as actual transpiration is also dependent on the microclimate conditions such as air temperature, humidity, wind, leaf surface area and canopy temperature difference. Therefore, difference of about 3.3% between cuvette and leaf temperature (Δ Tc-Tl) as observed in the present investigation may also provide microenvironment that is helpful in preventing fruit cracking in mulched plants. In December, however, the trends were not so distinct even though there were indications of relationship of branch water status with cracking of fruits borne on these branches.

Among the foliar treatments, no spray treatment recorded highest cracking percentage (39.39)

Table 1. Variation in different physiological parameters recorded in November (N) and December (D) individually and per cent cracking under different growing conditions.

Treatment	Cracking (%)	LWP (-bars)		RWC (%)		Pn (umol/ m²/s)		Trans (mmol/ m²/s)		SC (mmol/ m²/s)		Δ (Tc-Tl) (0C)	
		N	D	N	D	N	D	N	D	N	D	N	D
T1	26.1	24.3	20.3	73.4	50.0	6.4	5.5	3.3	3.8	168.0	137.8	1.1	1.0
T2	31.1	25.0	23.3	70.8	78.4	5.9	3.2	3.6	3.5	169.2	185.3	0.9	1.6
T3	37.8	27.8	21.0	63.2	72.6	6.2	3.3	3.2	3.7	148.5	209.6	0.75	1.3
T4	39.4	27.1	19.3	44.4	68.5	6.7	3.8	3.1	3.5	149.2	125.2	0.98	1.0
Mulching													
M1	28.3	24.7	21.9	66.2	66.3	6.8	3.8	3.13	3.7	154.5	166.6	0.94	1.2
M2	38.9	27.4	20.1	59.8	68.4	5.9	4.1	3.5	3.6	163.0	162.2	0.91	1.2
TxMulch													
T1M1	18.0	22.6	22.3	73.6	59.1	6.4	4.7	3.4	3.7	172.7	114.6	1.26	0.6
T1M2	34.2	26.0	18.3	73.2	40.9	6.5	6.3	3.3	3.8	163.5	161.0	0.85	1.4
T2M1	23.9	23.7	22.7	77.0	72.3	7.1	3.7	3.1	4.1	154.0	246.7	0.86	1.7
T2M2	38.4	26.3	24.0	64.6	84.6	4.7	2.6	4.1	3.1	184.5	124.0	0.95	1.5
T3M1	32.8	27.0	24.0	50.9	71.1	6.8	3.2	2.9	4.0	138.0	208.7	0.86	1.1
T3M2	42.8	28.7	18.0	75.5	74.1	5.7	3.4	3.6	3.5	159.0	210.7	0.65	1.4
T4M1	38.6	25.6	18.6	63.0	62.9	6.8	3.7	3.2	3.1	153.5	97.0	0.76	1.4
T4M2	40.2	28.6	20.0	25.8	74.1	6.6	3.9	3.1	4.0	145.0	153.3	1.2	0.6
CD Treat.	4.91	NS	NS	7.2	10.5	NS	NS	NS	NS	14.75	NS	NS	NS
CD Mul.	6.94	2.4	NS	NS	NS	0.62	NS	0.36	NS	NS	NS	NS	NS
CD TxM	NS	NS	4.12	14.36	14.87	1.25	NS	NS	NS	20.87	NS	0.36	NS

(LWP: Leaf water potential, RWC: Relative water content, Pn: photosynthetic rate, Trans: transpiration rate, SC: stomatal conductance, Δ (Tc-Tl): leaf -air temperature difference.

which was closely followed by water spray (37.83). Lower RWC and comparable (or higher) plant water potential in water sprayed compared to no spray plants (Table 1) clearly reflects relationship between cracking and plant water status.

Foliar spray of aqueous solution as T1 and T2 recorded significant reduction in per cent cracking. The minimum cracking was observed in borax+ $ZnSO_4$ which was statistically at par with that observed under borax+kaolin+$ZnSO_4$. Further, combinations of foliar sprays along with mulching of tree basin were more effective in reducing fruit cracking (Table 1). Positive influence of boron and zinc on water uptake and transport besides influencing activities of enzymes involved in protein, carbohydrate and nucleic acid metabolism may be responsible for reduction in cracking (Rab and Haq, 6; Sadeghzadeh, 8). As water demand during fruit growth and development is to be met from leaf following source-sink gradient relationship (Hepaksoi *et al*., 3), plant water gradient induces the process of water loss either through canopy surface or fruit surface to atmosphere in soil-plant-atmosphere continuum and thus greatly influences water relations and hence lead to incidence of cracking in fruits.

It is also reported that the cracking is more evident when the fruits are at maturity stage. It has been observed that during drought period, strengthened tissues (skin) lose their ability to divide and enlarge (Holland *et al*., 4). In our study too, fruit cracking began in early December and increased exponentially as the fruits matured till harvest time (data not presented). Here the role of rind thickness is envisaged, that has been reported in our earlier work (Singh *et al.,* 11) to be maximum in fruits obtained from pomegranate trees foliar sprayed with combination of borax, kaolin and zinc sulphate. Further, it is quite likely that rind thickness influence elasticity of fruit skin which in turns checks cracking. However, in contrast, Saei *et al*. (9) reported that not only the skin of fruits but some other physico-chemical characters mediated biomechanical forces on the growing fruits making them susceptible to cracking.

Per cent fruit cracking was negatively correlated (-0.41) with relative water content of leaves, while it was positively correlated (0.45) with water potential in November (Table 2). In our earlier work too, fruit cracking among twelve pomegranate cultivars was similarly correlated with leaf relative water content and water potential (Singh *et al.*, 10). Cracking percentage was also found slightly correlated with stomata conductance measured during November (r = 0.25 at p<0.10). However, as no significant correlation was observed between cracking and any of the physiological parameters studied in December this clearly indicates that plant water status of November possibly influences the cracking in fruits more in the present study. Additionally, it is also quite possible that plant water potential and leaf relative water content may directly influence photosynthesis, transpiration and related parameters which in turn indirectly influence fruit growth and cracking. Strong positive correlation in November between water potential of fruiting branch and stomatal conductance (0.48), a parameter that is known to influence gas exchange and subsequently photosynthesis and transpiration, is a reflection of existence of such a relationship in the present study. Further, positive correlation of relative water content of leaves with stomatal conductance (0.37) and Δ Tc-Tl (-0.32) estimated in November also indicated role of plant water status in processes (photosynthesis, transpiration and gas exchange) involved in plant growth.

Since, good correlation was observed between cracking percentage and physiological parameters, it was thought of developing model for predicting the occurrence of cracking percentage from physiological parameters. For this purpose, multiple linear regression based model was developed in which cracking percentage was kept as independent variable or predicted variables whereas physiological parameters were kept as dependent variable or predictors. Stepwise regression analysis was followed using 'lm' function of R programming environment. Developed regression equation is shown below in Eq (1):

Cracking per cent = 56.46 + 1.2945* × LWP-N - 1.4766** × LWP-D - 0.4925*** × RWC-N- 0.2949* × RWC-D + 2.2652* × Pn-N + 8.8774* × trans_N - 7.5369 × trans_D + 0.1055* × SC-D (R2 = 0.60) (1)

The symbol *, ** and *** in Eq (1) indicates that the respective coefficients of the equation is significant at 5%, 1% and 0.1%. The developed regression model will be quite useful for estimation of cracking percentage in pomegranate from the physiological parameters. Even, the model may guide to develop new varieties of pomegranate not susceptible to cracking focusing on the targeted physiological parameters. The validity of the developed model is tested on the experimental dataset and the scatter plot of observed and predicted cracking percentage is shown in Fig. 1. Most of the data points lie close to the 1:1 line, which shows the good estimation of cracking percentage in pomegranate by the developed model.

The present study established a relationship between cracking and selected physiological parameters. The results showed that fruit cracking

Table 2. Correlation matrix between cracking percentage and physiological parameters of pomegranate.

	Crack %	LWP N	LWP D	RWC N	RWC D	Pn N	Pn D	Trans N	Trans_ D	SC N	SC D	Δ (Tc-Tl) N	Δ (Tc-Tl) D
crack_%	1												
LWP -N	0.45*	1											
LWP-D	-0.13	0.17	1										
RWC-N	-0.41*	-0.28	-0.26	1									
RWC-D	-0.02	0.15	-0.13	-0.25	1								
Pn -N	0.08	-0.29	-0.19	-0.05	-0.41*	1							
Pn-D	0.02	-0.03	0.21	0.22	-0.35	0.08	1						
Trans_N	0.04	-0.17	0.01	0.25	0.18	-0.46*	-0.28	1					
Trans_D	-0.11	-0.10	0.14	-0.21	0.10	0.12	0.34	-0.62**	1				
SC-N	-0.25	-0.48*	0.04	0.37	-0.04	-0.40	-0.15	0.77**	-0.31	1			
SC-D	-0.01	-0.06	-0.05	0.08	0.25	0.13	0.12	-0.38	0.77	-0.24	1		
Δ (Tc-Tl)-N	-0.27	-0.13	0.25	-0.32	-0.07	0.25	0.04	-0.31	0.24	-0.01	-0.16	1	
Δ (Tc-Tl)-D	0.02	-0.19	-0.12	0.27	0.01	-0.14	-0.13	0.08	0.19	0.34	0.49*	-0.47*	1

* and ** indicates significance level at p<0.05 and p<0.01, respectively.

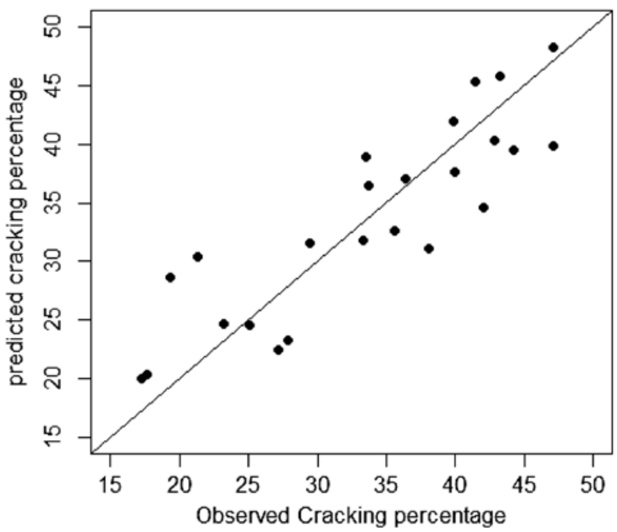

Fig. 1. Observed and predicted cracking percentage in pomegranate as estimated through regression based model using physiological parameters as input

could be minimized through managing physiological parameters influencing plant water status. Foliar sprays of borax 0.4%+ zinc sulphate 0.5%+ kaolin 4% and borax 0.4%+ zinc sulphate 0.5% are associated with less incidence of cracking possibly because of their effect on plant water status and leaf gas exchange parameters influencing transpiration and photosynthesis as observed in present study.

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